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ABSTRACT

The purpose of this wastewater treatment field study training program is to: (1) develop new qualified wastewater treatment plant operators; (2) expand the abilities of existing operators, permitting better service both to employers and public; and (3) prepare operators for civil service and certification examinations (examinations administered by state/professional associations which operators take to indicate a level of professional competence). This 10-chapter volume contains information on: the treatment plant operator; why we should treat wastes; wastewater treatment facilities; racks, screens, comminutors and grit removal; sedimentation and filtration; trickling filters; rotating biological contactors; activated sludge; and disinfection and chlorination. Objectives, glossary, lessons, questions (with suggested answers), and a test are provided for each chapter. A final examination (with answers), solving water treatment plant arithmetic problems, water abbreviations, complete glossary, and subject index are provided in an appendix. Program scope/sequence and instructions to participants in home-study courses are provided in the introduction. (TW)

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A FIELD STUDY TRAINING PROGRAM

VOLUME

ED294755

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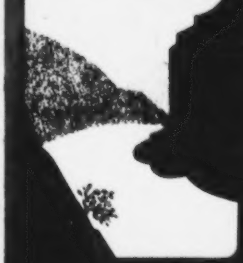

2

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OPERATION OF WASTEWATER TREATMENT PLANTS

Third Edition

VOLUME I

A Field Study Training Program

prepared by

California State University, Sacramento
(formerly Sacramento State College)
Department of Civil Engineering

in cooperation with the
California Water Pollution Control Association

****

Kenneth D. Kerri, Project Director
Bill B. Dendy, Co-Director
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****

for the

Environmental Protection Agency
Office of Water Program Operations
Municipal Permits and Operations Division
First Edition, Technical Training Grant No. 5TT1-WP-16-03 (1970)
Second Edition, Grant No. T900690010

1988

OPERATOR TRAINING MANUALS IN THIS SERIES are available from Ken Kerri, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819, phone (916) 278-6142.

1. **Operation of Wastewater Treatment Plants**, 2 Volumes,
2. **Operation and Maintenance of Wastewater Collection Systems**, 2 Volumes,
3. **Industrial Waste Treatment,**
4. **Advanced Waste Treatment,**
5. **Treatment of Metal Wastestreams,**
6. **Pretreatment Facility Inspection,**
7. **Water Treatment Plant Operation,** 2 Volumes,
8. **Small Water System Operation and Maintenance,** and
9. **Water Distribution System Operation and Maintenance.**

NOTICE

This manual is revised and updated before each printing based on comments from persons using the manual.

FIRST EDITION

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First printing, 1985	8,000
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5

PREFACE TO THE FIRST EDITION

The purposes of this home study program are:

a. to develop qualified treatment plant operators;
b. to expand the abilities of existing operators, permitting better service to both their employers and the public; and
c. to prepare operators for *CERTIFICATION EXAMINATIONS*.[1]

To provide you with information needed to operate wastewater treatment plants as efficiently as possible, experienced plant operators prepared the material on treatment plant processes. Each chapter begins with an introduction and then discusses start up, daily operation, interpretation of lab results and possible approaches to solving operational problems. This order of topics was determined during the testing program on the basis of operators' comments indicating the information they needed most urgently. Additional chapters discuss maintenance, safety, sampling, laboratory procedures, hydraulics, records, analysis and presentation of data, and report writing.

Plant influents (raw wastewater) and the efficiencies of treatment processes vary from plant to plant and from location to location. The material contained in this program is presented to provide you with an understanding of the basic operational aspects of your plant and with information to help you analyze and solve operational problems. This information will help you operate your plant as efficiently as possible.

Wastewater treatment is a rapidly advancing field. To keep pace with scientific advances, the material in this program must be periodically revised and updated. This means that you, the operator, must recognize the need to be aware of new advances and the need for continuous training beyond this program.

Originally the concepts for this manual evolved from Mr. Larry Trumbull, 1967 Chairman of the Operator Training Committee of the California Water Pollution Control Association. Messrs. Bill Dendy and Kenneth Kerri, Project Directors, investigated possible means of financial support to develop and test the manual and prepared a successful application to the Federal Water Pollution Control Administration (5TT1-WP-16-03). The chapters were written, tested by pilot groups of operators and potential operators, reviewed by consultants and the Federal Water Quality Administration, and rewritten in accordance with the suggestions from these sources.

The project directors are indebted to the many operators and other persons who contributed to the manual. Every effort was made to acknowledge material from the many excellent references in the wastewater treatment field. Special thanks are due Messrs. John Brady and William Crooks who both contributed immensely to the manual. Mr. F.J. Ludzack, Chemist, National Training Center, Environmental Protection Agency, Water Quality Office, offered many technical improvements. A note of thanks is also due our typists, Miss Linda Smith, Mrs. Gloria Uri, Mrs. Daryl Rasmussen, Mrs. Vicki Sadlem, Mrs. Peggy Courtney, and Mrs. Pris Jernigan. Illustrations were drawn by Mr. Martin Garrity.

Following the first year of use by over 6500 operators and persons interested in operation, minor editing changes were necessary to correct typing errors and omissions and also to rewrite and expand questions and sections that could be clarified. Improvements suggested by operators using the manual were summarized and forwarded to a special Technical Advisory Task Force composed of operators familiar with the manual. This Task Force was formed as a subcommittee of the Water Pollution Control Federation's Personnel Advancement Committee and was chaired by Mr. Sam Warrington. We gratefully thank John Brady, Carlos Doyle, Otto Havens, Wilbur Holst, William Johnson, F.J. Ludzack and David Vandersommen for their efforts to improve our original version.

Kenneth D. Kerri
Bill Dendy

1973

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[1] *Certification examination.* ***An examination administered by a state or professional association that operators take to indicate a level of professional competence. In most states the Chief Operator of a plant must be "certified" (successfully pass a certification examination), and in a few states certification is voluntary. Current trends indicate that certification of operators will be mandatory in all states in the near future.***

PREFACE TO THE SECOND EDITION

During the 1970's many people decided that something must be done to control water pollution. The United States Congress passed the "Federal Water Pollution Control Act Amendments of 1972" (PL 92-500) and subsequent amendments. The objective of this Act is to restore and maintain the quality of the Nation's waters. In order to achieve this objective, the Act contains provisions for a financial grant program to assist municipalities with the planning, construction, start up and training of personnel in publicly-owned wastewater treatment plants. Grant funds have been used to build many new plants to date and many more plants will be built in the future. These plants are becoming more complex and are requiring operators with higher levels of knowledge and skills in order to insure that the plants produce a high quality effluent.

This manual, *OPERATION OF WASTEWATER TREATMENT PLANTS*, was used by over 40,000 persons interested in the operation of treatment plants during the 1970's. Every year when more manuals were printed, the manual was updated on the basis of comments and suggestions provided by persons using the manual. After six years of use by operators, the authors, the California Water Pollution Control Association, and the U.S. Environmental Protection Agency (EPA) decided that the contents of the manual should be reexamined, updated and revised. To accomplish this task, EPA provided the Foundation of California State University, Sacramento, with a grant to conduct the necessary studies, writing and field tests.

Recently the U.S. Environmental Protection Agency and the Association of Boards of Certification (ABC) have undertaken studies to document "need to know" tasks performed by wastewater treatment plant operators, skills required, alternative methods of training, training material needs and availability, and the development of instructional materials for certification examinations. Every effort has been made to incorporate the results of these studies in this Second Edition of *OPERATION OF WASTEWATER TREATMENT PLANTS*.

The project directors are indebted to the many operators and other persons who contributed to the Second Edition. Material from the many excellent references in the wastewater treatment field has been acknowledged wherever possible. Joe Bahnick, Ken Hay, Adelaide Lilly, Frank Lapensee and Bob Rose, U.S. Environmental Protection Agency, served ably as resource persons, consultants and advisers. Special thanks are due our project consultants, Mike Mulbarger, Carl Nagel and Al Petrasek who provided technical advice. Our education reviewers were George Gardner and Larry Hannah. Christine Umeda and Marlene Itagaki administered the national field testing program. A note of thanks was well earned by our typists Charlene Arora, Elaine Saika and Gladys Kornweibel. Illustrations were drawn by Martin Garrity.

Kenneth D. Kerri
John Brady

1980

7

USES OF THIS MANUAL

Originally this manual was developed to serve as a home-study course for operators in remote areas or persons unable to attend formal classes either due to shift work, personal reasons or the unavailability of suitable classes. This home-study training program used the concepts of self-paced instruction where you are your own instructor and work at your own speed. In order to certify that a person had successfully completed this program, an objective test was included at the end of each chapter and the training course became a correspondence or self-study type of program.

Once operators started using this manual for home study, they realized that it could serve effectively as a textbook in the classroom. Many colleges and universities have used the manual as a text in formal classes often taught by operators. In areas where colleges were not available or were unable to offer classes in the operation of wastewater treatment plants, operators and utility agencies joined together to offer their own courses using the manual.

Occasionally a utility agency has enrolled from three to over 300 of its operators in this training program. A manual is purchased for each operator. A senior operator or a group of operators are designated as instructors. These operators help answer questions when the persons in the training program have questions or need assistance. The instructors grade the objective tests at the end of each chapter, record scores and notify California State University, Sacramento, of the scores when a person successfully completes this program. This approach avoids the long wait while papers are being graded and returned by CSUS.

This manual was prepared to help operators run their treatment plants. Please feel free to use it in the manner which best fits your training needs and the needs of other operators. We will be happy to work with you to assist you in developing your training program. Please feel free to contact

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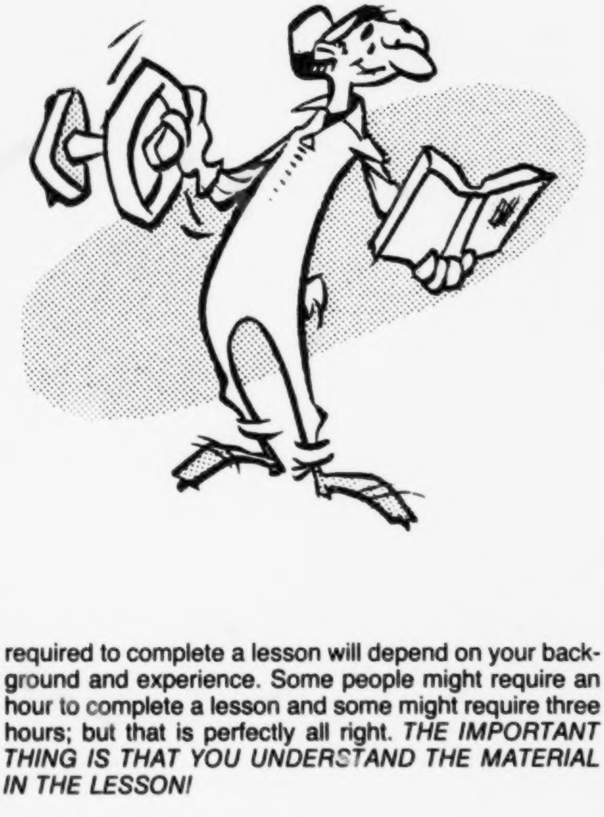
INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE

Procedures for reading the lessons and answering the questions are contained in this section.

To progress steadily through this program, you should establish a regular study schedule. For example, many operators in the past have set aside two hours during two evenings a week for study.

The study material is contained in three volumes divided into 29 chapters. Some chapters are longer and more difficult than others. For this reason, many of the chapters are divided into two or more lessons. The time required to complete a lesson will depend on your background and experience. Some people might require an hour to complete a lesson and some might require three hours; but that is perfectly all right. *THE IMPORTANT THING IS THAT YOU UNDERSTAND THE MATERIAL IN THE LESSON!*



Each lesson is arranged for you to read a short section, write the answers to the questions at the end of the section, check your answers against suggested answers; and then *YOU* decide if you understand the material sufficiently to continue or whether you should read the section again. You will find that this procedure is slower than reading a normal textbook, but you will remember much more when you have finished the lesson.

At the end of each chapter, you will find an "objective test." Mark your answers on the special answer sheet provided for each chapter. Some discussion and review questions are provided following each lesson in the later chapters. These questions review the important points you have covered in the lesson.

The objective test at the end of each lesson contains true or false, multiple-choice, fill-in-the-blank, or match-the-answers types of questions. The purposes of this exam are to review the chapter and to give experience in taking different types of exams. *MAIL TO THE PROGRAM DIRECTOR ONLY YOUR ANSWERS TO OBJECTIVE TESTS ON THE PROVIDED ANSWER SHEETS.*

After you have completed the last objective test, you will find a final examination. This exam is provided for you to review how well you remembered the material. You may wish to review the entire manual before you take the final exam. Some of the questions are essay-type questions which are used by some states for higher-level certification examinations. After you have completed the final examination, grade your own paper and determine the areas in which you might need additional review before your next examination.

You are your own teacher in this program. You could merely look up the suggested answers from the answer sheet or copy them from someone else, but you would not understand the material. Consequently, you would not be able to apply the material to the operation of your plant nor recall it during an examination for certification or a civil service position.

YOU WILL GET OUT OF THIS PROGRAM WHAT YOU PUT INTO IT.

SUMMARY OF PROCEDURE

A. OPERATOR (YOU)

1. Read what you are expected to learn in each chapter (from Chapter 4 on, the major topics are listed at the beginning of the chapter).
2. Read sections in lesson.
3. Write answers to questions at end of sections in your notebook. You should write the answers to the questions just like you would if these were questions on a test.
4. Check your answers with suggested answers.
5. Decide whether to reread section or to continue with the next section.
6. Write answers to discussion and review questions at the end of lessons in your notebook.
7. Mark answers to objective test on answer sheet.
8. Mail material to project director.

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Operation of Wastewater Treatment Plants
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B. PROJECT DIRECTOR

1. Mails answer sheet for each chapter to operator.
2. Corrects tests, answers any questions, and returns results to operators.

C. ORDER OF WORKING LESSONS

To complete this program you will have to work all of the chapters. You may proceed in numerical order, or you may wish to work some lessons sooner. The Arithmetic Appendix, "How to Solve Wastewater Treatment Plant Arithmetic Problems," may be worked before Chapter 4 because Chapter 4 requires the use of simple arithmetic. If you have trouble with the problems in chapter 4 or some of the following chapters, you may find it helpful to refer to the arithmetic appendix or you may decide to work the arithmetic appendix first.

Chapter 16, "Laboratory Procedures and Chemistry," in Volume II may be studied with Chapter 5 because the operation of sedimentation and flotation treatment processes requires some laboratory tests. Again, you may wish to refer to the lab chapter while working on Chapter 5 and the other chapters, or you may wish to work the lab chapter first.

SAFETY IS A VERY IMPORTANT TOPIC. Everyone working in a treatment plant must always be safety conscious. You must take extreme care with your personal hygiene to prevent the spread of disease to yourself and your family. Operators in treatment plants daily encounter situations and equipment that can cause a serious disabling injury or illness if the operator is not aware of the potential danger and does not exercise adequate precautions. For these reasons, you may decide to work on the chapter on "Plant Safety and Good Housekeeping" early in your studies. In each chapter *SAFE PROCEDURES ARE ALWAYS STRESSED.*

10

COURSE OUTLINE

VOLUME I, THIRD EDITION

Chapter	Topic	Page
1	The Treatment Plant Operator	1
2	Why Treat Wastes?	11
3	Wastewater Treatment Facilities	25
4	Racks, Screens, Comminutors and Grit Removal	55
5	Sedimentation and Flotation	101
6	Trickling Filters	155
7	Rotating Biological Contactors	197
8	Activated Sludge (Package Plants and Oxidation Ditches)	227
9	Waste Treatment Ponds	275
10	Disinfection and Chlorination	319
Appendix	Final Examination	397
	How to Solve Wastewater Treatment Plant Arithmetic Problems	405
	Glossary	445
	Index	475

TECHNICAL CONSULTANTS, FIRST EDITION

William Garber
George Gardner
Carl Nagel
Joe Nagano
Frank Phillips
Warren Prentice
Ralph Stowell
Larry Trumbull

TECHNICAL CONSULTANTS, SECOND EDITION

George Gardner
Larry Hannah
Mike Mulbarger
Carl Nagel
Al Petrasek

COURSE OUTLINE

VOLUME II, THIRD EDITION

Chapter	Topic	Page
11	Activated Sludge (Conventional Activated Sludge Plants)	1
12	Sludge Digestion and Solids Handling	107
13	Effluent Disposal	197
14	Plant Safety and Good Housekeeping	219
15	Maintenance	253
16	Laboratory Procedures and Chemistry	349
17	Applications of Computers for Plant O&M	489
18	Analysis and Presentation of Data	503
19	Records and Report Writing	535
Appendix	Final Examination	553
	Glossary	588
	Index	617

ADVANCED WASTE TREATMENT COURSE OUTLINE

1	Odor Control	1
2	Activated Slugde	31
3	Solids Handling and Disposal	115
4	Solids Removal from Secondary Effluents	265
5	Phosphorus Removal	337
6	Nitrogen Removal	365
7	Wastewater Reclamation	393
8	Instrumentation	433
Appendix	Final Examination	494
	Glossary	503
	Index	535

CHAPTER 1

THE TREATMENT PLANT OPERATOR

by

Larry Trumbull

and

William Crooks

TABLE OF CONTENTS

Chapter 1. The Treatment Plant Operator

Page

1.0 What is a Treatment Plant Operator? 3

1.01 What does a Treatment Plant Operator do? 3

1.02 Who does the Treatment Plant Operator work for? 3

1.03 Where does the Treatment Plant Operator work? 3

1.04 What pay can a Treatment Plant Operator expect? 3

1.05 What does it take to be a Treatment Plant Operator? 3

1.1 Your Personal Training Course 4

1.2 What Do You Already Know? 4

1.3 The Water Quality Protector: *YOU* 4

1.4 Your Qualifications 5

1.41 Your Job 5

1.5 Manpower Needs and Future Job Opportunities 6

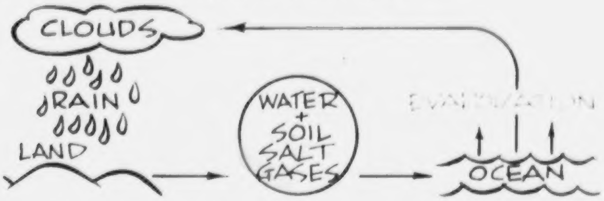
1.6 Training Yourself to Meet the Needs 7

CHAPTER 1. THE TREATMENT PLANT OPERATOR

This portion of Chapter 1 was prepared especially for the new or the potential *WASTEWATER*[1] treatment plant operator. If you are an experienced operator, you may find some new viewpoints.

1.0 WHAT IS A TREATMENT PLANT OPERATOR?

Before modern society entered the scene, water was purified in a natural cycle as shown below:



Simplified natural purification cycle

But modern society and the intensive use of the water resource and the resulting water pollution could not wait for sun, wind, and time to accomplish the purification of soiled water; consequently, treatment plants were built. Thus, nature was given an assist by a team consisting of designers, builders, and treatment plant operators. Designers and builders occupy the scene only for an interval, but operators go on forever. They are the final and essential link in maintaining and protecting the aquatic environment upon which all life depends.

1.01 What does a Treatment Plant Operator do?

Simply described, the operator keeps a wastewater (sewage) treatment plant working. Physically the operator turns valves, pushes switches, collects samples, lubricates equipment, reads gages and records data.

An operator may also maintain equipment and plant area by painting, weeding, gardening, repairing and replacing. Mentally an operator inspects records, observes conditions, makes calculations to determine that the plant is working effectively, and predicts necessary maintenance and facility needs to assure continued effective operation of the plant. The operator also has an obligation to explain to supervisors, councils, civic bodies, and the general public what the plant does, and most importantly, why its continued and expanded financial support is vital to the welfare of the community.

1.02 Who does the Treatment Plant Operator work for?

An operator's paycheck usually comes from a city, sanitation district, or other public agency. The operator may, however, be employed by one of the many large industries which operate their own treatment plants. As an operator you are responsible to your employer for maintaining an economically and efficiently operating facility. An even greater obligation rests with the operator because the great numbers of people who rely upon downstream water supplies are totally dependent upon the operator's competence and trustworthiness for their welfare. In the final analysis, the operator is really working for these vitally affected downstream water users.

1.03 Where does the Treatment Plant Operator work?

Obviously the operator works in a wastewater treatment plant. But the different types and locations of treatment plants offer a wide range of working conditions. From the mountains to the sea, wherever people congregate into communities, wastewater treatment plants will be found. From a unit process operator at a complex municipal facility to a one-person manager of a small town plant, you can select your own special place in treatment plant operation.

1.04 What pay can a Treatment Plant Operator expect?

In dollars? Prestige? Job satisfaction? Community service? In opportunities for advancement? By whatever scale you use, returns are what you make them. If you choose a large municipality, the pay is good and advancement prospects are tops. Choose a small town and pay may not be as good; but job satisfaction, freedom from time-clock hours, community service, and prestige may well add up to outstanding personal achievement. Total reward depends on you.

The operator's duties

1.05 What does it take to be a Treatment Plant Operator?

Desire. First you must choose to enter this profession. You can do it with a grammar school, a high school, or a college education. While some jobs will always exist for manual labor, the real and expanding need is for *TRAINED OPERATORS*. New techniques, advanced equipment, and increasing instrumentation require a new breed of operator, one who is willing to learn today, and gain tomorrow, for surely your plant will move towards newer and more effective operating procedures and treatment processes. Indeed, the truly service-minded operator assists in adding to and improving the plant performance on a continuing basis.

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[1] ***Wastewater.*** *The used water and solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."*

Tomorrow's forgotten operator stopped learning yesterday

You can be an operator tomorrow by beginning your learning today; or you can be a better operator, ready for advancement, by accelerating your learning today.

This training course, then, is your start towards a better tomorrow, both for you and for the public who will receive better water from your efforts.

QUESTIONS

Place an "X" by the correct answer or answers. After you have answered all the questions, check your answers with those given at the end of the chapter on page 8. Reread any sections you did not understand and then proceed to the next section. You are your own teacher in this training program, and *YOU* should decide when you understand the material and are ready to continue with new material.

EXAMPLE

This is a training course on

________ A. Accounting
________ B. Engineering
___X____ C. Wastewater Treatment Plant Operation
________ D. Salesmanship.

1.0A. Wastewater is the same thing as:
________ A. Rain
________ B. Soil
________ C. Sewage
________ D. Condensation.

1.0B. What does an operator do?
________ A. Collect samples.
________ B. Lubricate equipment.
________ C. Record data.

1.0C. Who employs Treatment Plant Operators?
________ A. Cities.
________ B. Sanitation districts.
________ C. Industries.

Check your answers on page 8.

1.1 YOUR PERSONAL TRAINING COURSE

Beginning on this page, you are embarking on a training course which has been carefully prepared to allow you to improve your knowledge of and ability to operate a wastewater treatment plant. You will be able to proceed at your own pace; you will have an opportunity to learn a little or a lot about each topic. The course has been prepared this way to fit the various needs of operators, depending on what kind of plant you have or how much you need to learn about it. To study for certification examinations, you will have to cover all the material. You will never know everything about your plant or about the wastewater which flows through it, but you can begin to answer some very important questions about how and when certain things happen in the plant. You can also learn to manipulate your plant so that it operates at maximum efficiency.

1.2 WHAT DO YOU ALREADY KNOW?

If you already have some experience operating a wastewater treatment plant, you may use the first three chapters for a review. If you are relatively new to the wastewater treatment field, these chapters will provide you with the background information necessary to understand the later chapters. The remainder of this introductory chapter describes your role as a *PROTECTOR OF WATER QUALITY*, your *QUALIFICATIONS* to do your job, a little about manpower needs in the wastewater treatment field, and some information on other *TRAINING OPPORTUNITIES*.

1.3 THE WATER QUALITY PROTECTOR: YOU

Historically Americans have shown a great lack of interest in the protection of their water resources. We have been content to think that "the solution to pollution is dilution." For years we were able to dump our wastes with little or no treatment back into the nearest *RECEIVING WATERS*.[2] As long as there was enough dilution water to absorb the waste material, nature took care of our disposal problems for us. As more and more towns and industry sprang up, waste loads increased until the natural purification processes could no longer do the job. Many waterways were converted into open sewers. Unfortunately, for many areas this did not signal the beginning of a clean-up campaign. It merely increased the frequency of the cry: "We don't have the money for a treatment plant," or the ever-popular, "If we make industries treat their wastes they will move to another state." Thus, the pollution of our waters increased.

POLLUTION
WATER QUALITY

Water quality protector

Within the last few years, we have seen many changes in this depressing picture. We now realize that we must give nature a hand by treating wastes before they are discharged. Adequate treatment of wastes will not only protect our health and that of our downstream neighbors; it can also increase property values, allow game fishing and various recreational uses to be enjoyed, and attract water-using industries to the area. Today we are seeing massive efforts being undertaken to control water pollution and improve water quality throughout the nation. This includes the efforts not only of your own community, county and state, but also the federal government.

Great sums of public and private funds are now being invested in large, complex municipal and industrial wastewater treatment facilities to overcome this pollution; and you, the treatment plant operator, will play a key role in the battle. Without efficient operation of your plant, much of the research, planning, and building that has been done and will be done to accomplish the goals of water quality control in your area will be wasted. You are the difference between a facility and a performing unit. You are, in fact, a *WATER QUALITY PROTECTOR* on the front line of the water pollution battle.

---

[2] ***Receiving Water.*** *A stream, river, lake, or ocean into which treated or untreated wastewater is discharged.*

Pollution

The receiving water quality standards and waste discharge requirements that your plant has been built to meet have been formulated to *PROTECT* the water users downstream from your plant. These uses may include domestic water supply, industrial water supply, agricultural water supply, stock and wildlife watering, propagation of fish and other aquatic and marine life, shellfish culture, swimming and other water contact sports, boating, esthetic enjoyment, hydroelectric power, navigation, and others.

Therefore, you have an obligation to the users of the water downstream, as well as to the people of your district or municipality. You are the *KEY WATER QUALITY PROTECTOR* and must realize that you are in a responsible position.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 8.

1.3A Why must municipal and industrial wastewaters receive adequate treatment?

1.3B How did many receiving waters become polluted?

1.4. YOUR QUALIFICATIONS

The skill and ability required for your job depend to a large degree on the size and type of treatment plant where you are employed. You may work at a large modern treatment plant serving several hundred thousand persons and employing a hundred or more operators. In this case you are probably a specialist in one or more phases of the treatment process.

On the other hand, you may operate a small plant serving only a thousand people or fewer. You may be the only operator at the plant or, at best, have only one or two additional employees. If this is the case, you must be a "jack-of-all trades" because of the diversity of your tasks.

1.41 Your Job

To describe the operator's duties, let us start at the beginning. Let us say that the need for a new or improved wastewater treatment plant has long been recognized by the community. The community has voted to issue the necessary bonds to finance the project, and the consulting engineers have submitted plans and specifications. It is to the best interests of the community and the consulting engineer that you be in on the ground floor planning. If it is a new plant, you should be present or at least available during the construction period in order to become completely familiar with the entire plant, including the equipment and machinery and their operation. This will provide you with the opportunity to relate your plant drawings to actual facilities.

You and the engineer should discuss how the treatment plant should best be run and the means of operation the designer had in mind when the plant was designed. If it is an old plant being remodeled, you are in a position to offer excellent advice to the consulting engineer. Your experience provides valuable technical knowledge concerning the characteristics of wastewater, its sources, and the limitations of the present facilities. Together with the consultant, you are a member of an expert team able to advise the district or city.

Once the plant is operating, you become an administrator. In a small plant your duties may not include supervision of personnel, but you are still in charge of records. You are responsible for operating the plant as efficiently as possible, keeping in

Visitors touring a treatment plant.

mind that the primary objective is to protect the receiving water quality by continuous and efficient plant performance. Without adequate, reliable records of every phase of operation, the effectiveness of your operation has not been documented (recorded).

You may also be the budget administrator. Most certainly you are in the best position to give advice on budget requirements, management problems, and future planning. You should be aware of the necessity for additional expenditures, including funds for plant enlargement, equipment replacement, and laboratory requirements. You should recognize and define such needs in sufficient time to inform the proper officials to enable them to accomplish early planning and budgeting.

You are in the field of public relations and must be able to explain the purpose and operation of your plant to visitors, civic organizations, school classes, representatives of news media, and even to city council or directors of your district. Public interest in water quality is increasing, and you should be prepared to conduct plant tours that will contribute to public acceptance and support. A well-guided tour for officials of regulatory agencies or other operators may provide these people with sufficient understanding of your plant to allow them to suggest helpful solutions to operational problems.

Special care and safety must be practiced when visitors are taken through your treatment plant. An accident could spoil all of your public relations efforts.

The appearance of your plant indicates to the visitor the type of operation you maintain. If the plant is dirty and rundown with flies and other insects swarming about, you will be unable to convince your visitors that the plant is doing a good job. *YOUR RECORDS SHOWING A HIGH-QUALITY EFFLUENT*[3] *WILL MEAN NOTHING TO THESE VISITING CITIZENS UNLESS YOUR PLANT APPEARS CLEAN AND WELL-MAINTAINED AND THE EFFLUENT LOOKS GOOD.*

Another aspect of your public relations duties is your dealings with the downstream water user. Unfortunately, the operator is often considered by the downstream user as a polluter rather than a water quality protector. Through a good public information program, backed by facts supported by reliable data, you can correct the impression held by the downstream user and establish "good neighbor" relations. This is indeed a challenge. Again, you must understand that you hold a very responsible position and be aware that the sole purpose of the operation of your plant is to protect the downstream user, be that user a private property owner, another city or district, an industry, or a fisherman.

You are required to understand certain laboratory procedures in order to conduct various tests on samples of wastewater and receiving waters. On the basis of the data obtained from these tests, you may have to adjust the operation of the treatment plant to meet stream standards or discharge requirements.

As an operator you must have a knowledge of the complicated mechanical principles involved in many treatment mechanisms. In order to measure and control the wastewater flowing through the plant, you must have some understanding of hydraulics. Practical knowledge of electrical motors, circuitry, and controls is also essential.

CLEAN STREAM!

Clean Stream

Safety is a very important operator responsibility. Unfortunately too many operators take safety for granted. This is one reason why the wastewater treatment industry has one of the worst safety records of any industry. *YOU* have the responsibility to be sure that your treatment plant is a safe place to work and visit. Everyone must follow safe procedures and understand why safe procedures must be followed at all times. All operators must be aware of the safety hazards in and around treatment plants. You should plan or be a part of an active safety program. Chief operators frequently have the responsibility of training new operators and should encourage all operators to become certified.

Clearly then, the modern day wastewater treatment plant operator must possess a broad range of qualifications.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 8.

1.4A Why is it important that the operator be present during the construction of a new plant?

1.4B How does the operator become involved in public relations?

1.5 MANPOWER NEEDS AND FUTURE JOB OPPORTUNITIES

The wastewater treatment field, like so many others, is changing rapidly. New plants are being constructed, and old plants are being modified and enlarged to handle the wastewater from our growing population and to treat the new chemicals being produced by our space age technology. Operators, maintenance personnel, foremen, managers, instrumentation experts, and laboratory technicians are sorely needed.

---

[3] *Effluent. Wastewater or other liquid – raw, partially or completely treated – flowing* FROM *a basin, treatment process, or treatment plant.*

A look at past records and future predictions indicates that wastewater treatment is a rapidly growing field. Municipalities employed approximately 20,000 operators in 1967 and over 67,000 operators in 1974. Industry employed approximately 3,500 operators in 1967 and around 12,000 plant operators by 1972.[4] In 1980 73,600 persons were employed in the wastewater treatment field and the need for new operators was estimated at 5,000 per year for every year up to the year 2000.[5] A report to Congress[6] in 1985 estimated that there were over 105,000 operators in the United States. The need for trained operators is increasing rapidly and is expected to continue in the future.

1.6 TRAINING YOURSELF TO MEET THE NEEDS

This training course is not the only one available to help you improve your abilities. The states have offered various types of both long- and short-term operator training through their health departments or water pollution control associations have provided training classes conducted by members of the associations, largely on a volunteer basis. The Water Pollution Control Federation has developed two visual aid training courses to complement its Manual of Practice No. 11. State and local colleges have provided valuable training under their own sponsorship or in partnership with others. Many state, local and private agencies have conducted both long- and short-term training as well as interesting and informative seminars. The California Water Pollution Control Association has prepared two textbooks, one on laboratory procedures and one on mathematics. Excellent textbooks have been written by many state agencies. Those of the New York State Health Department and the Texas Water Utilities Association deserve special attention. The Canadian government has developed very good training manuals for operators.

Listed below are several very good references in the field of wastewater treatment plant operation that are frequently referred to throughout this course. The name in quotes represents the term usually used by operators when they mention the reference. Prices listed are those available when this manual was published and will probably increase in the future.

1. *"MOP 11." OPERATION OF WASTEWATER TREATMENT PLANTS, WPCF* Manual of Practice No. 11, Water Pollution Control Federation, Publications Order Department, 601 Wythe Street, Alexandria, VA 22314-1994. Order #M0012DT. Price $31.00 to members; $41.50 to others plus $4.75 postage and handling.
2. *"NEW YORK MANUAL." MANUAL OF INSTRUCTION FOR WASTEWATER TREATMENT PLANT OPERATORS*, distributed in New York by the New York State Department of Health, Office of Public Health Education, Water Pollution Control Board. Distributed outside of New York State by Health Education Service, P.O. Box 7126, Albany, New York 12224. Price $13.75. Make check payable to Health Research Inc.
3. *"TEXAS MANUAL." MANUAL OF WASTEWATER OPERATIONS*, prepared by Texas Water Utilities Association. Obtainable from Texas Water Utilities Association, 6521 Burnet Lane, Austin, Texas 78757. Price $18.00, plus $1.20 postage.

These publications cover the entire field of treatment plant operation. At the end of many of the chapters yet to come, lists of other references will be provided.

---

[4] *Data contained in this paragraph were obtained from "Manpower and Training Needs in Water Pollution Control," Report of the Department of the Interior, Federal Water Pollution Control Administration to the Congress of the United States, Senate Document No. 49, 90th Congress, First Session, Washington, D.C., 1967 and from "Study of Municipal Wastewater Treatment Plant Manpower and Training Needs and Resources," Municipal Permits and Operations Division, Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C., 1974.*

[5] *Bryant, James O., "Manpower Needs in Wastewater Treatment and Collection Systems for the Years 1980-2000." Paper presented at the Third Annual NETA National Conference and Workshop, Seattle, Washington, August 11, 1981.*

[6] *"Report to Congress on Training for Operators of Publicly owned Wastewater Treatment Plants." Office of Municipal Pollution Control, U.S. Environmental Protection Agency, Washington, DC 20460, February 1985.*

SUGGESTED ANSWERS

Chapter 1. THE TREATMENT PLANT OPERATOR

You are not expected to have the exact answer suggested for questions requiring written answers, but you should have the correct idea. The numbering of the questions refers to the section in the manual where you can find the information to answer the questions. Answers to questions numbered 1.0 can be found in Section 1.0, What is a Treatment Plant Operator?

Answers to questions on page 4.

1.0A. C

1.0B. A, B, C

1.0C. A, B, C

Answers to questions on page 5.

1.3A. Municipal and industrial wastewaters must receive adequate treatment to protect receiving water users.

1.3B. Receiving waters became polluted by a lack of public concern for the impact of waste discharges and by discharging wastewater into a receiving water beyond its natural purification capacity.

Answers to questions on page 6.

1.4A The operator should be present during the construction of a new plant in order to become familiar with the plant before the operator begins operating it.

1.4B The operator becomes involved in public relations by explaining the purpose and operation of the plant to visitors, civic organizations, newspaper people, and supervisors.

DIRECTIONS FOR WORKING OBJECTIVE TEST

Chapter 1. THE TREATMENT PLANT OPERATOR

1. You have been provided with a special answer sheet for each chapter. Be sure you follow the special directions provided with the answer sheets. If you lose an answer sheet or have any problems, please notify the Project Director.
2. Mark your answers on the answer sheet with a dark lead pencil. Do not use ink.

   For example, Question 2 has three correct answers (1, 2 and 3). Therefore, you should place a mark under Columns 1, 2 and 3 on the answer sheet.

   Questions 4 through 7 are true or false questions. If a question is true, then mark Column 1, and if false mark Column 2. The correct answer to Question 4 is true; therefore, place a mark in Column 1.

   Please mark your answers in your workbook for your record because answer sheets will not be returned to you.
3. Mail answer sheet to the Project Director immediately after you have completed the test.
4. Answer sheets may be folded (but not into more than 3 equal parts) and mailed in a 4 x 9½ standard white envelope.

OPERATION OF WASTEWATER TREATMENT PLANTS

IMPORTANT

PLEASE READ INSTRUCTIONS ON REVERSE SIDE BEFORE COMPLETING THIS FORM.

TM

OFFICE USE ONLY
DO NOT MARK
●

Name: OPERATOR JOE B.
Last First MI

Address: 711 MAIN ST
CLEARWATER, CA 01234
City State Zip Code

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
1	2	3-	4	5-	6	7	8	9		
0	0	0	0	0	0	0	0	0	●	0
●	1	1	1	1	1	1	1	1	1	●
2	●	2	2	2	2	2	2	2	2	2
3	3	●	3	3	3	3	3	3	3	3
4	4	4	●	4	4	4	4	4		4
5	5	5	5	●	5	5	5	5		5
6	6	6	6	6	●	6	6	6		6
7	7	7	7	7	7	●	7	7		7
8	8	8	8	8	8	8	●	8		8
9	9	9	9	9	9	9	9	●		9

Mail to:
Professor Kenneth Kerri
California State University, Sacramento
6000 Jay Street
Sacramento, California 95819

FOLD --

IMPORTANT DIRECTIONS FOR MARKING ANSWERS

Use black lead pencil only (# 2 or softer).
Make heavy black marks that fill the circle completely.
Erase clearly any answer you wish to change.
Make no stray marks on this answer sheet.

1. MULTIPLE CHOICE QUESTIONS: Fill in the correct answers. If 2 and 3 are correct for question 1, mark:

   1 2 3 4 5
   1 Ⓣ ● ● ○ ○

2. TRUE–FALSE QUESTIONS: If true, fill in the circle in column 1; if false, fill in column 2. If question 3 is true, mark:

   1 2 3 4 5
   3 ● Ⓕ ○ ○ ○

EXAMPLE

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
1	2	3	4	5	6	7	8	9	0	1
0	0	0	0	0	0	0	0	0	●	0
●	1	1	1	1	1	1	1	1	1	●
2	●	2	2	2	2	2	2	2	2	2
3	3	●	3	3	3	3	3	3	3	3
4	4	4	●	4	4	4	4	4		4
5	5	5	5	●	5	5	5	5		5
6	6	6	6	6	●	6	6	6		6
7	7	7	7	7	7	●	7	7		7
8	8	8	8	8	8	8	●	8		8
9	9	9	9	9	9	9	9	●		9

NCS Trans-Optic F 6298 54321

FOLD --

	1 2 3 4 5		1 2 3 4 5		1 2 3 4 5		1 2 3 4 5		1 2 3 4 5		1 2 3 4 5
1	Ⓣ Ⓕ ○ ○ ○	11	Ⓣ Ⓕ ○ ○ ○	21	Ⓣ Ⓕ ○ ○ ○	31	Ⓣ Ⓕ ○ ○ ○	41	Ⓣ Ⓕ ○ ○ ○	51	Ⓣ Ⓕ ○ ○ ○
2	● ● ● ○ ○	12	Ⓣ Ⓕ ○ ○ ○	22	Ⓣ Ⓕ ○ ○ ○	32	Ⓣ Ⓕ ○ ○ ○	42	Ⓣ Ⓕ ○ ○ ○	52	Ⓣ Ⓕ ○ ○ ○
3	Ⓣ Ⓕ ○ ○ ○	13	Ⓣ Ⓕ ○ ○ ○	23	Ⓣ Ⓕ ○ ○ ○	33	Ⓣ Ⓕ ○ ○ ○	43	Ⓣ Ⓕ ○ ○ ○	53	Ⓣ Ⓕ ○ ○ ○
4	● Ⓕ ○ ○ ○	14	Ⓣ Ⓕ ○ ○ ○	24	Ⓣ Ⓕ ○ ○ ○	34	Ⓣ Ⓕ ○ ○ ○	44	Ⓣ Ⓕ ○ ○ ○	54	Ⓣ Ⓕ ○ ○ ○
5	Ⓣ Ⓕ ○ ○ ○	15	Ⓣ Ⓕ ○ ○ ○	25	Ⓣ Ⓕ ○ ○ ○	35	Ⓣ Ⓕ ○ ○ ○	45	Ⓣ Ⓕ ○ ○ ○	55	Ⓣ Ⓕ ○ ○ ○
6	Ⓣ Ⓕ ○ ○ ○	16	Ⓣ Ⓕ ○ ○ ○	26	Ⓣ Ⓕ ○ ○ ○	36	Ⓣ Ⓕ ○ ○ ○	46	Ⓣ Ⓕ ○ ○ ○	56	Ⓣ Ⓕ ○ ○ ○
7	Ⓣ Ⓕ ○ ○ ○	17	Ⓣ Ⓕ ○ ○ ○	27	Ⓣ Ⓕ ○ ○ ○	37	Ⓣ Ⓕ ○ ○ ○	47	Ⓣ Ⓕ ○ ○ ○	57	Ⓣ Ⓕ ○ ○ ○
8	Ⓣ Ⓕ ○ ○ ○	18	Ⓣ Ⓕ ○ ○ ○	28	Ⓣ Ⓕ ○ ○ ○	38	Ⓣ Ⓕ ○ ○ ○	48	Ⓣ Ⓕ ○ ○ ○	58	Ⓣ Ⓕ ○ ○ ○
9	Ⓣ Ⓕ ○ ○ ○	19	Ⓣ Ⓕ ○ ○ ○	29	Ⓣ Ⓕ ○ ○ ○	39	Ⓣ Ⓕ ○ ○ ○	49	Ⓣ Ⓕ ○ ○ ○	59	Ⓣ Ⓕ ○ ○ ○
10	Ⓣ Ⓕ ○ ○ ○	20	Ⓣ Ⓕ ○ ○ ○	30	Ⓣ Ⓕ ○ ○ ○	40	Ⓣ Ⓕ ○ ○ ○	50	Ⓣ Ⓕ ○ ○ ○	60	Ⓣ Ⓕ ○ ○ ○

SAMPLE
DO NOT USE

OBJECTIVE TEST

Chapter 1. THE TREATMENT PLANT OPERATOR

Please mark correct answers on the answer sheet. There may be more than one correct answer to each question.

1. The used water and solids from a community that flow to a treatment plant are called ____________?
   1. Effluent
   2. Mixed Liquor
   3. Sludge
   4. Wastewater

2. Receiving water uses protected by an operator include
   1. Boating.
   2. Drinking water supply.
   3. Fishing.
   4. None of these

3. What kinds of jobs are available in the wastewater treatment field in addition to those available for operators?
   1. Foremen
   2. Instrumentation experts
   3. Laboratory technicians
   4. Maintenance personnel
   5. Manager

TRUE OR FALSE:

4. In many treatment plants the operator must be a "jack-of-all-trades."
   1. True
   2. False

5. A treatment plant operator is a *WATER QUALITY* protector.
   1. True
   2. False

6. Plant visitors are impressed by records showing efficient plant operation, and their opinions are never influenced by the appearance of the plant and grounds.
   1. True
   2. False

7. After finishing this program, an operator will need to continue to study in order to keep pace with changes occurring in the field.
   1. True
   2. False

END OF OBJECTIVE TEST

CHAPTER 2

WHY TREAT WASTES?

by

William Crooks

TABLE OF CONTENTS

Chapter 2. Why Treat Wastes?

Page

PRONUNCIATION KEY 13

GLOSSARY 14

2.0 Prevention of Pollution 16

2.1 What is Pure Water? 16

2.2 Types of Waste Discharges 16

2.3 Effects of Waste Discharges 17

- 2.30 Sludge and Scum 17
- 2.31 Oxygen Depletion 17
- 2.32 Human Health 18
- 2.33 Other Effects 18

2.4 Solids in Wastewater 18

- 2.40 Types of Solids 19
- 2.41 Total Solids 19
- 2.42 Dissolved Solids 19
- 2.43 Suspended Solids 19
- 2.44 Organic and Inorganic Solids 20
- 2.45 Floatable Solids 20

2.5 Natural Cycles 21

2.6 NPDES Permits 21

2.7 Arithmetic Assignment 21

2.8 Additional Reading 21

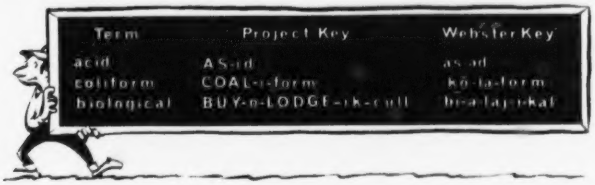
2.9 Review 21

PROJECT PRONUNCIATION KEY

by Warren L. Prentice

The Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this Key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This Key is designed solely to aid operators in this program.

You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation Key. Each Key will be different from each other and from this Key. Examples of the differences between the Key used in this program and the *WEBSTERS NEW WORLD DICTIONARY* "Key[1]" are shown below:



Term	Project Key	Webster Key
acid	AS-id	as-id
coliform	COAL-i-form	kō-lə-form
biological	BUY-o-LODGE-ik-cull	bī-ə-läj-i-kəl

In using this Key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Project Key.

	Syllable				
	1st	2nd	3rd	4th	5th
Word					
acid	AS	id			
coliform	COAL	i	form		
biological	BUY	o	LODGE	ik	cull

The first word *ACID* has its first syllable accented. The second word, *COLIFORM,* has its first syllable accented. The third word, *BIOLOGICAL,* has its first and third syllables accented.

We hope you will find the Key useful in unlocking the pronunciation of any new word.

---

[1] *The* WEBSTER'S NEW WORLD DICTIONARY, *College Edition, 1968, was chosen rather than an unabridged dictionary because of its availability to the operator. Other editions may be slightly different.*

GLOSSARY

Chapter 2. WHY TREAT WASTES?

AEROBIC BACTERIA
(AIR-O-bick back-TEAR-e-ah)
AEROBIC BACTERIA

Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobic bacteria.

ANAEROBIC BACTERIA
(AN-air-O-bick back-TEAR-e-ah)
ANAEROBIC BACTERIA

Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4).

BIOCHEMICAL OXYGEN DEMAND (BOD)
BIOCHEMICAL OXYGEN DEMAND

The rate at which microorganisms use oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BIOCHEMICAL OXYGEN DEMAND (BOD) TEST
BIOCHEMICAL OXYGEN DEMAND TEST

A procedure that measures the rate of oxygen use under controlled conditions of time and temperature. Standard test conditions include dark incubation at 20°C for a specified time (usually five days).

COLIFORM (COAL-i-form)
COLIFORM

One type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes other environmental sources.

DISINFECTION (dis-in-FECK-shun)
DISINFECTION

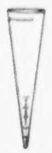
The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorination being most frequently used in water and wastewater treatment plants. Compare with STERILIZATION.

EFFLUENT (EF-lu-ent)
EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

IMHOFF CONE
IMHOFF CONE

A clear, cone-shaped container marked with graduations. The cone is used to measure the volume of settleable solids in a specific volume of wastewater.



INORGANIC WASTE (IN-or-GAN-nick)
INORGANIC WASTE

Waste material such as sand, salt, iron, calcium, and other materials which are only slightly affected by the action of organisms. Inorganic wastes are chemical substances of mineral origin; whereas organic wastes are chemical substances usually of animal or plant origin.

MILLIGRAMS PER LITER, mg/*L*
MILL-i-GRAMS per LEET-er)
MILLIGRAMS PER LITER, mg/*L*

A measure of the concentration by weight of a substance per unit volume. For practical purposes, one mg/*L* is equal to one part per million parts (ppm). Thus, a liter of water with a specific gravity of 1.0 weighs one million milligrams; and if it contains 10 milligrams of dissolved oxygen, the concentration is 10 milligrams per million milligrams, or 10 milligrams per liter (10 mg/*L*), or 10 parts of oxygen per million parts of water, or 10 parts per million (10 ppm).

NUTRIENT CYCLE
NUTRIENT CYCLE

The transformation or change of a nutrient from one form to another until the nutrient has returned to the original form, thus completing the cycle. The cycle may take place under either aerobic or anaerobic conditions.

NUTRIENTS NUTRIENTS

Substances which are required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen, and phosphorus. Nitrogen and phosphorus are difficult to remove from wastewater by conventional treatment processes because they are water soluble and tend to recycle. Also see NUTRIENT CYCLE.

ORGANIC WASTE (or-GAN-nick) ORGANIC WASTE

Waste material which comes mainly from animal or plant sources. Organic waste generally can be consumed by bacteria and other small organisms. Inorganic wastes are chemical substances of mineral origin.

PATHOGENIC ORGANISMS (path-o-JEN-nick) PATHOGENIC ORGANISMS

Bacteria, viruses or cysts which can cause disease (typhoid, cholera, dysentery). There are many types of bacteria which do *NOT* cause disease and which are *NOT* called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.

pH (PEA-A-ch) pH

Technically, this is the logarithm of the reciprocal of the hydrogen-ion concentration, which is explained in Chapter 16, "Laboratory Procedures and Chemistry." For now, it is sufficient to understand that pH expresses the intensity of the acid or basic condition of a liquid. The pH may range from 0 to 14, where 0 is most acid and 14 is most basic, and 7 is neutral. Most natural waters have a pH between 6.5 and 8.5

POLLUTION POLLUTION

Any change in the natural state of water which interferes with its beneficial reuse or causes failure to meet water-quality requirements.

PRIMARY TREATMENT PRIMARY TREATMENT

A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

RECEIVING WATER RECEIVING WATER

A stream, river, lake or ocean into which treated or untreated wastewater is discharged.

SECONDARY TREATMENT SECONDARY TREATMENT

A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

SEPTIC (SEP-tik) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

STABILIZE STABILIZE

To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.

STERILIZATION (stare-uh-luh-ZAY-shun) STERILIZATION

The removal or destruction of all living microorganisms, including pathogenic and saprophytic bacteria, vegetative forms, and spores. Compare with DISINFECTION.

TRANSPIRATION (TRAN-spear-RAY-shun) TRANSPIRATION

The process by which water vapor is lost to the atmosphere from living plants.

CHAPTER 2. WHY TREAT WASTES?

2.0 PREVENTION OF POLLUTION

The operator's main job is to protect the many users of receiving waters. As an operator you must do the best you can to remove any substances which will unreasonably affect these users.

Many people think *ANY* discharge of waste to a body of water is pollution. However, with our present system of using water to carry away the waste products of home and industry, it would be impossible and perhaps unwise to prohibit the discharge of all wastewater to oceans, streams, and groundwater basins. Present day technology is capable of treating wastes in such a manner that existing or potential receiving water uses are not unreasonably affected. Definitions of pollution include any interference with beneficial reuse of water or failure to meet water quality requirements. Any questions or comments regarding this definition must be settled by the appropriate enforcement agency.

2.1 WHAT IS PURE WATER?

Water is a combination of two parts hydrogen and one part oxygen, or H_2O. This is true, however, only for "pure" water such as might be manufactured in a laboratory. Water as we know it is not "pure" hydrogen and oxygen. Even the distilled water we purchase in the store has measurable quantities of various substances in addition to hydrogen and oxygen. Rain water, even before it reaches the earth, contains many substances. These substances, since they are not found in "pure" water, may be considered "impurities." When rain falls through the atmosphere, it gains nitrogen and other gases. As soon as the rain flows overland, it begins to dissolve from the earth and rocks such substances as calcium, magnesium, sodium, chloride, sulfate, iron, nitrogen, phosphorus, and many other materials. Organic matter (matter derived from plants and animals) is also dissolved by water from contact with decaying leaves, twigs, grass, or small insects and animals. Thus it should be realized that a fresh flowing mountain stream may pick up many natural "impurities," some possibly in harmful amounts, before it ever reaches civilization or is affected by the waste discharges of society. Many of these substances, however, are needed in small amounts to support life and be useful to humans. Concentrations of impurities must be controlled or regulated to prevent harmful levels in receiving waters.

Water + Impurities

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 23.

2.1A What are some of the dissolved substances in water?

2.1B How does water pick up dissolved substances?

2.2 TYPES OF WASTE DISCHARGES

The waste discharge that first comes to mind in any discussion of stream pollution is the discharge of domestic wastewater. Wastewater contains a large amount of *ORGANIC WASTE.*[1] Industry also contributes substantial amounts of organic waste. Some of these organic industrial wastes come from vegetable and fruit packing; dairy processing; meat packing; tanning; and processing of poultry, oil, paper and fiber (wood), and many more.

Another classification of wastes is *INORGANIC WASTES.*[2]

---

[1] *Organic Waste (or-GAN-nick). Waste material which comes mainly from animal or plant sources. Organic waste generally can be consumed by bacteria and other small organisms, Inorganic wastes are chemical substances of mineral origin.*

[2] *Inorganic Waste (IN-or-GAN-nick). Waste material such as sand, salt, iron, calcium, and other materials which are only slightly affected by the action of organisms. Inorganic wastes are chemical substances of mineral origin; whereas organic wastes are chemical substances usually of animal or plant origin.*

Domestic wastewater contains inorganic material as well as organic, and many industries discharge inorganic wastes which add to the mineral content of receiving waters. For instance, a discharge of salt brine (sodium chloride) for water softening will increase the amount of sodium and chloride in the receiving waters. Some industrial wastes may introduce inorganic substances such as chromium or copper, which are very toxic to aquatic life. Other industries (such as gravel washing plants) discharge appreciable amounts of soil, sand or grit, which also may be classified as inorganic waste.

There are two other major types of wastes that do not fit either the organic or inorganic classification. These are heated (thermal) wastes and radioactive wastes. Waters with temperatures exceeding the requirements of the enforcing agency may come from cooling processes used by industry and from thermal power stations generating electricity. Radioactive wastes are usually controlled at their source, but could come from hospitals, research laboratories, and nuclear power plants.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 23.

2.2A Several of the following contain significant quantities of organic material. Which are they?

- a. Domestic Wastewater
- b. Cooling Water from Thermal Power Stations
- c. Paper Mill Wastes
- d. Metal Plating Wastes
- e. Tanning Wastes

2.2B List four types of pollution.

2.3 EFFECTS OF WASTE DISCHARGES

Certain substances not removed by wastewater treatment processes can cause problems in receiving waters. This section reviews some of these substances and discusses why they should be treated.

2.30 Sludge and Scum

If certain wastes (including domestic wastewater) do not receive adequate treatment, large amounts of solids may accumulate on the banks of the receiving waters, or they may settle to the bottom to form sludge deposits or float to the surface and form rafts of scum. Sludge deposits and scum are not only unsightly but, if they contain organic material, they may also cause oxygen depletion and be a source of odors. *PRIMARY TREATMENT*[3] units in the wastewater treatment plant are designed and operated to remove the sludge and scum before they reach the receiving waters.

2.31 Oxygen Depletion

Most living creatures need oxygen to survive, including fish and other aquatic life. Although most streams and other surface waters contain less than 0.001% *DISSOLVED OXYGEN* (10 milligrams of oxygen per liter of water, or 10 mg/*L*,[4] most fish can thrive if there are at least 5 mg/*L* and other conditions are favorable. When oxidizable wastes are discharged to a stream, bacteria begin to feed on the waste and decompose or break down the complex substances in the waste into simple chemical compounds. These bacteria also use dissolved oxygen (similar to human respiration or breathing) from the water and are called *AEROBIC BACTERIA*.[5] As more organic waste is added, the bacteria reproduce rapidly; and as their population increases, so does their use of oxygen. Where waste flows are high, the population of bacteria may grow large enough to use the entire supply of oxygen from the stream faster than it can be replenished by natural diffusion from the atmosphere. When this happens, fish and most other living things in the stream which require dissolved oxygen die.

Oxygen depletion

Therefore, one of the principal objectives of wastewater treatment is to prevent as much of this "oxygen-demanding" organic material as possible from entering the receiving water. The treatment plant actually removes the organic material the same way a stream does, but it accomplishes the task much more efficiently by removing the wastes from the wastewater. *SECONDARY TREATMENT*[6] units are designed and operated to use natural organisms such as bacteria *IN THE PLANT* to *STABILIZE*[7] and to remove organic material.

Another effect of oxygen depletion, in addition to the killing of fish and other aquatic life, is the problem of odors. When all the dissolved oxygen has been removed, *ANAEROBIC BACTERIA*[8] begin to use the oxygen which is combined chemically with other elements in the form of chemical compounds, such as sulfate (sulfur and oxygen), which are also dissolved in the water. When anaerobic bacteria remove the oxygen from sulfur compounds, hydrogen sulfide (H_2S), which has a "rotten egg" odor, is produced. This gas is not only very odorous, but it also erodes concrete and can discolor and remove paint from homes and structures. Hydrogen sulfide also may form explosive mixtures with air and is capable of paralyzing your respiratory center. Other products of anaerobic decomposition (putrefaction: PU-tree-FACK-shun) also can be objectionable.

---

[3] *Primary Treatment. A wastewater treatment process which takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.*

[4] *Milligrams per Liter, mg/L* (MILL-i-GRAMS per LEET-er). A measure of the concentration by weight of a substance per unit volume. For practical purposes, one mg/*L* is equal to one part per million parts (ppm). Thus, a liter of waste with a specific gravity of 1.0 weighs one million milligrams; and if it contains 10 milligrams of dissolved oxygen, the concentration is 10 milligrams per million milligrams, or 10 milligrams per liter (10 mg/*L*), or 10 parts of oxygen per million parts of water, or 10 parts per million (10 ppm).

[5] *Aerobic Bacteria (AIR-O-bick back-TEAR-e-ah). Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobic bacteria.*

[6] *Secondary Treatment. A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.*

[7] *Stabilize. To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.*

[8] *Anaerobic Bacteria (AN-air-O-bick back-TEAR-e-ah). Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4) and nitrate (NO_3).*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 23.

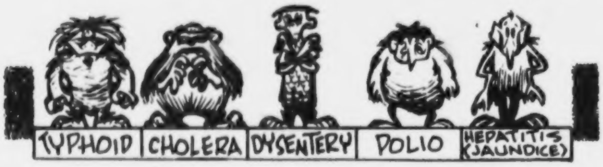
2.3A What causes oxygen depletion when organic wastes are discharged to the water?

2.3B What kind of bacteria cause hydrogen sulfide gas to be released?

2.32 Human Health

Up to now we have discussed the physical or chemical effects that a waste discharge may have on the uses of water. More important, however, may be the effect on human health through the spread of disease-causing bacteria and viruses. Initial efforts to control human wastes evolved from the need to prevent the spread of diseases. Although untreated wastewater contains many billions of bacteria per gallon, most of these are not harmful to humans, and some are even helpful in wastewater treatment processes. However, humans who have a disease which is caused by bacteria or viruses may discharge some of these harmful organisms in their body wastes. Many serious outbreaks of communicable diseases have been traced to direct contamination of drinking water or food supplies by the body wastes from a human disease carrier.

Some known examples of diseases which may be spread through wastewater discharges are



Diseases

Fortunately these bacteria that grow in the intestinal tract of diseased humans are not likely to find the environment in the wastewater treatment plant or receiving waters favorable for their growth and reproduction. Although many of these *PATHOGENIC ORGANISMS*[9] are removed by natural die-off during the normal treatment processes, sufficient numbers can remain to cause a threat to any downstream use involving human contact or consumption. If these uses exist downstream, the treatment plant must also include a *DISINFECTION*[10] process.

The disinfection process historically employed is the addition of chlorine. In most cases proper chlorination of a *WELL-TREATED WASTE* will result in essentially a complete kill of these pathogenic bacteria. The operator must realize, however, that breakdown or malfunction of equipment could result in the discharge at any time of an effluent which contains pathogenic bacteria.

2.33 Other Effects

Some wastes adversely affect the clarity and color of the receiving waters, making them unsightly and unpopular for recreation.

Many industrial wastes are highly acid or alkaline (basic), and either condition can interfere with aquatic life, domestic use, and other uses. An accepted measurement of a waste's acid or basic condition is its *pH.*[11] Before wastes are discharged, they should have a pH similar to that of the receiving water.

Waste discharges may contain toxic substances, such as heavy metals or cyanide, which may affect the use of the receiving water for domestic purposes or for aquatic life. Plant effluents chlorinated for disinfection purposes may have to be dechlorinated to protect receiving waters from the toxic effects of residual chlorine.

Taste- and odor-producing substances may reach levels in the receiving water which are readily detectable in drinking water or in the flesh of fish.

Treated wastewaters contain *NUTRIENTS*[12] capable of encouraging excess algae and plant growth in receiving waters. These growths hamper domestic, industrial, and recreational uses. Conventional wastewater treatment plants do not remove a major portion of the nitrogen and phosphorus nutrients.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 23.

2.3C Where do the disease-causing bacteria in wastewater come from?

2.3D What is the term which means "disease-causing"?

2.3E What is the most frequent means of disinfecting treated wastewater?

2.4 SOLIDS IN WASTEWATER (Fig. 2.1)

One of the primary functions of a treatment plant is the removal of solids from wastewater.

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[9] *Pathogenic Organisms (path-o-JEN-nick). Bacteria, viruses or cysts which can cause disease. There are many types of bacteria which do* NOT *cause disease and which are* NOT *called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.*

[10] *Disinfection (dis-in-FECK-shun). The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorination being most frequently used in water and wastewater treatment plants. Compare with STERILIZATION.*

[11] *pH. Technically, this is the logarithm of the reciprocal of the hydrogen-ion concentration, which is explained in Chapter 16, "Laboratory Procedures and Chemistry." For now, it is sufficient to understand that pH expresses the intensity of the acid or basic condition of a liquid. The pH may range from 0 to 14, where 0 is most acid and 14 is most basic, and 7 is neutral. Most natural waters have a pH between 6.5 and 8.5.*

[12] *Nutrients. Substances which are required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen and phosphorus. Nitrogen and phosphorus are difficult to remove from wastewater by conventional treatment processes because they are water soluble and tend to recycle. Also see NUTRIENT CYCLE.*

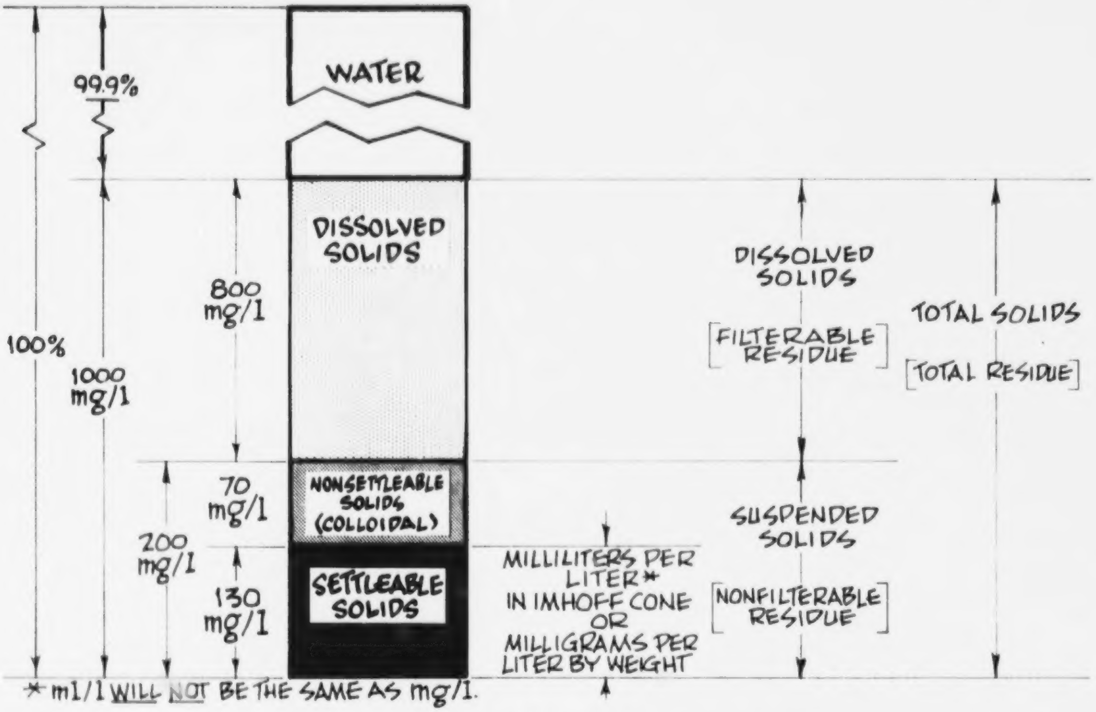

Fig. 2.1 Typical composition of solids in raw wastewater (floatable solids not shown)

2.40 Types of Solids

In Section 2.2 you read about the different *TYPES* of pollution: organic, inorganic, thermal, and radioactive. For a normal municipal wastewater which contains domestic wastewater as well as some industrial and commercial wastes, the concerns of the treatment plant designer and operator usually are to remove the organic and inorganic *SUSPENDED SOLIDS*, to remove the *DISSOLVED ORGANIC SOLIDS* (the treatment plant does little to remove *DISSOLVED INORGANIC SOLIDS*), and to kill the *PATHOGENIC ORGANISMS* by disinfection. *THERMAL* and *RADIOACTIVE* wastes require special treatment processes.

Since the main purpose of the treatment plant is removal of solids from the wastewater, a detailed discussion of the types of solids is in order. The figure above will help you understand the different terms.

2.41 Total Solids

For discussion purposes assume that you obtain a one-liter sample of raw wastewater entering the treatment plant. Heat this sample enough to evaporate all the water and weigh all the solid material left (residue); it weighs 1000 milligrams. Thus, the *TOTAL SOLIDS* concentration in the sample is 1000 milligrams per liter (mg/*L*). This weight includes both *DISSOLVED* and *SUSPENDED* solids.

2.42 Dissolved Solids

How much is dissolved and how much is suspended? To determine this you could take an identical sample and filter it through a very fine mesh filter such as a membrane filter or fiberglass. The suspended solids will be caught on the filter, and the dissolved solids will pass through with the water. You can now evaporate the water and weigh the residue to determine the weight of *DISSOLVED SOLIDS*. In the figure above the amount is shown as 800 mg/*L*. The remaining 200 mg/*L* is suspended solids. Dissolved solids are also called *FILTERABLE RESIDUE*.[13]

2.43 Suspended Solids

Suspended solids are composed of two parts: settleable and nonsettleable. The difference between settleable and nonsettleable solids depends on the size, shape, and weight per unit volume of the solid particles; large-sized particles tend to settle more rapidly than smaller particles. The amount of settleable solids in the raw wastewater should be estimated in order to design settling basins (primary units), sludge pumps, and sludge handling facilities. Also, measuring the amount of settleable solids entering and leaving the settling basin allows you to calculate the efficiency of the basin for removing the settleable solids. A device called an *IMHOFF CONE*[14] is used to measure settleable solids in milliliters per liter, ml/*L*. (The example in the figure above shows a settleable solids concentration of 130 mg/*L*. The settled solids in the Imhoff Cone had to be dried and weighed by proper procedures to determine their weight.)

You may calculate the weight of nonsettleable solids by substracting the weight of dissolved and settleable solids from the weight of total solids. In the figure above the nonsettleable solids concentration is shown as 70 mg/*L*. Suspended solids are also called *NONFILTERABLE RESIDUE*.[13]

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[13] *"Standard Methods" (also Chapter 16, Section 16.5, "Laboratory Procedures for NPDES Monitoring") defines* FILTERABLE *residue as solids that* PASS THROUGH *a filter and* nonfilterable *residue as those solids that* DO NOT PASS THROUGH *a filter.*

[14] *Imhoff Cone. A clear, cone-shaped container marked with graduations. The cone is used to measure the volume of settleable solids in a specific volume of wastewater.*

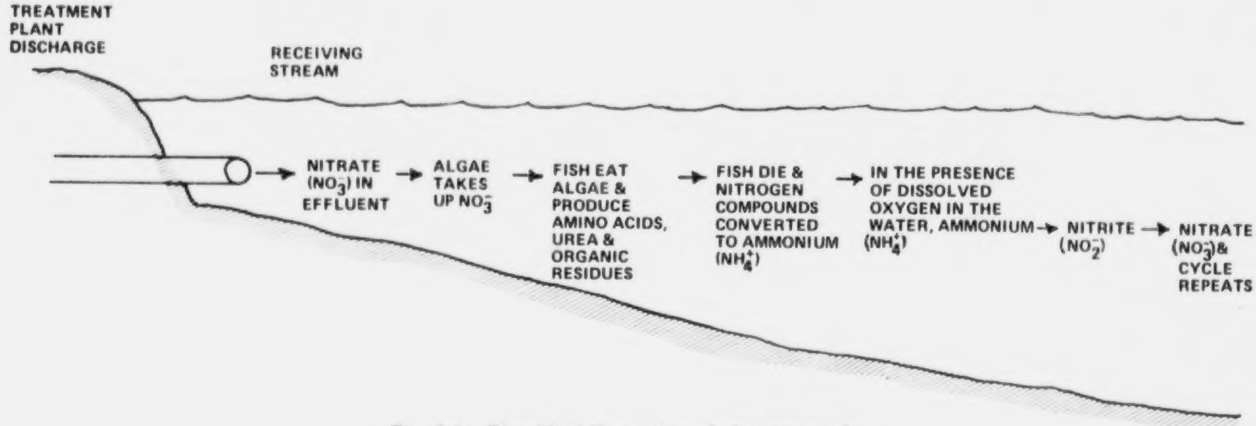
TREATMENT PLANT DISCHARGE
RECEIVING STREAM
NITRATE (NO_3^-) IN EFFLUENT
ALGAE TAKES UP NO_3^-
FISH EAT ALGAE & PRODUCE AMINO ACIDS, UREA & ORGANIC RESIDUES
FISH DIE & NITROGEN COMPOUNDS CONVERTED TO AMMONIUM (NH_4^+)
IN THE PRESENCE OF DISSOLVED OXYGEN IN THE WATER, AMMONIUM (NH_4^+)
NITRITE (NO_2^-)
NITRATE (NO_3^-)& CYCLE REPEATS

Fig. 2.2 Simplified illustration of nitrogen cycle

2.44 Organic and Inorganic Solids

For total solids or for any separate type of solids, such as dissolved, settleable, or nonsettleable, the relative amounts of organic and inorganic matter can be determined. This information is important for estimating solids handling capacities and for designing treatment processes for removing the organic portion in waste. The organic portion can be very harmful to receiving waters.

2.45 Floatable Solids

There is no standard method for the measurement and evaluation of floatable solids. Since treatment units are designed to remove these solids in raw wastewater and treated effluent. Floatable solids are undesirable in the plant effluent from an aesthetic viewpoint because the sight of floatables in receiving waters indicates the presence of inadequately treated wastewater.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 23.

2.4A An Imhoff Cone is used to measure ________ solids.

2.4B Why is it necessary to measure settleable solids?

2.4C Total solids consist of ________ and ________ solids, both of which contain organic and inorganic matter.

2.5 NATURAL CYCLES (Fig. 2.2)

When the treated wastewater from a plant is discharged into *RECEIVING WATERS*[15] such as streams, rivers or lakes, natural cycles in the aquatic (water) environment may become upset. Whether any problems are caused in the receiving waters depends on the following factors:

1. Type or degree of treatment,
2. Size of flow from the treatment plant,
3. Characteristics of wastewater from treatment plant,
4. Amount of flow in the receiving stream or volume of receiving lake that can be used for dilution,
5. Quality of the receiving waters,
6. Amount of mixing between *EFFLUENT*[16] and receiving waters, and
7. Uses of receiving waters.

Natural cycles of interest in wastewater treatment include the natural purification cycles such as the cycle of water from evaporation or *TRANSPIRATION*[17] to condensation to precipitation to runoff and back to evaporation, the life cycles of aquatic organisms, and the cycles of nutrients. These cycles are occurring continuously in wastewater treatment plants and in receiving waters at different rates depending on environmental conditions. Treatment plant operators control and accelerate these cycles to work for their benefit in treatment plants and in receiving waters rather than have these cycles cause plant operational problems and disrupt downstream water uses.

NUTRIENT CYCLES[18] are a special type of natural cycle because of the sensitivity of some receiving waters to nutrients. Important nutrients include carbon, hydrogen, oxygen, sulfur, nitrogen and phosphorus. All of the nutrients have their own cycles, yet each cycle is influenced by the other cycles. These nutrient cycles are very complex and involve chemical changes in living organisms.

To illustrate the concept of nutrient cycles, a simplified version of the nitrogen cycle will be used as an example. A wastewater treatment plant discharges nitrogen in the form of nitrate (NO_3^-)in the plant effluent to the receiving waters. Algae take up the nitrate and produce more algae. The algae are eaten by fish which convert the nitrogen to amino acids, urea and organic residues. If the fish die and sink to the bottom, these nitrogen compounds can be converted to ammonium (NH_4^+). In the presence of dissolved oxygen and special bacteria, the ammonium is converted to nitrite (NO_2^-), then to nitrate (NO_3^-), and finally the algae can take up the nitrate and start the cycle all over again.

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[15] *Receiving Water. A stream, river, lake, or ocean into which treated or untreated wastewater is discharged.*

[16] *Effluent (EF-lu-ent). Water or other liquid – raw, partially or completely treated – flowing* FROM *a basin, treatment process, or treatment plant.*

[17] *Transpiration (TRAN-spear-RAY-shun). The process by which water vapor is lost to the atmosphere from living plants.*

[18] *Nutrient Cycle. The transformation or change of a nutrient from one form to another until the nutrient has returned to the original form, thus completing the cycle. The cycle may take place under either aerobic or anaerobic conditions.*

If too much nitrogen is discharged to receiving waters, too many algae could be produced. Water with excessive algae can be unsightly. Bacteria decomposing dead algae from occasional die offs can deplete the dissolved oxygen and cause a fish kill. Thus, the nitrogen cycle has been disrupted, as well as the other nutrient cycles. If no dissolved oxygen is present in the water, the nitrogen compounds are converted to ammonium (NH_4^+), the carbon compounds to methane (CH_4), and the sulfur compounds to hydrogen sulfide (H_2S). Ammonia (NH_3) and hydrogen sulfide are odorous gases. Under these conditions the receiving waters are *SEPTIC;*[19] they stink and look terrible. Throughout this manual you will be provided information on how to control these nutrient cycles in your treatment plant in order to treat wastes and to control odors, as well as to protect receiving waters.

2.6 NPDES PERMITS (Fig. 2.3)

NPDES stands for **N**ational **P**ollutant **D**ischarge **E**limination **S**ystem. NPDES permits are required by the Federal Water Pollution Control Act Amendments of 1972 with the intent of making the Nation's waters suitable for swimming and for fish and wildlife. The permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal treatment plants, large agricultural feed lots and return irrigation flows. An industry discharging into municipal collection and treatment systems need not obtain a permit but must meet certain specified pretreatment standards. These permits may outline a schedule of compliance for a wastewater treatment facility such as dates for the completion of plant design, engineering, construction and/or treatment process changes. Instructions for completing NPDES reporting forms and the necessary forms are available from the regulatory agency issuing the permit.

Your main concern as an operator is the effluent (discharge) limitations specified in the NPDES permit for your plant. The permit may specify monthly average and maximum levels of settleable solids, suspended solids (nonfilterable residue), biochemical oxygen demand (*BOD*)[20] and the most probable number (MPN) of *COLIFORM*[21] group bacteria. Larger plants must report effluent temperatures because of the impact of temperature changes on natural cycles. Also, average and maximum flows may be identified as well as an acceptable range of pH values. Almost all effluents are expected to contain virtually no substances which would be toxic to organisms in the receiving waters. The NPDES permit will specify the frequency of collecting samples and the methods of reporting the results. Details on how to comply with NPDES permits will be provided throughout this manual.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 23.

2.5A Why should an operator have an understanding of natural cycles?

2.5B What can happen when nutrient cycles are disrupted and there is no dissolved oxygen in the receiving water?

2.6A What does NPDES stand for?

2.7 ARITHMETIC ASSIGNMENT

A good way to learn how to solve arithmetic problems is to work on them a little bit at a time. In this operator training manual we are going to make a short arithmetic assignment at the end of every chapter. If you will work this assignment, you can easily learn how to solve wastewater treatment arithmetic problems.

Turn to the Appendix at the back of this manual and read the following sections in "How to Solve Waterwater Treatment Plant Arithmetic Problems."

1. *OBJECTIVES,*
2. A.0 *HOW TO STUDY THIS APPENDIX,* and
3. A.1 *BASIC ARITHMETIC*

Solve all of the problems in Sections A.10, Addition; A.11, Subtraction; A.12, Multiplication; A.13, Division; A.14, Multiplication and Division; A.15, Actual Problems; A.16, Percentage; and A.17, Sample Problems Involving Percent. Try to use an electronic pocket calculator.

2.8 ADDITIONAL READING

For a detailed discussion of the physical and chemical composition of wastewater, you may wish to refer to the following sources:

1. *MOP 11,* Chapter 3, "Characterization of Wastewater*."
2. *NEW YORK MANUAL,* Chapter 1, "Wastewater."
3. *TEXAS MANUAL,* Chapter 1, "Wastewater, Its Composition, Chemistry and Biology."

* Actual chapter number and title may depend on edition.

2.9 REVIEW

In this chapter you have read why it is necessary to treat wastewater, something about the types of waste discharges and their effects, and a brief description of the different kinds of solids in wastewater. This is intended to be only a general discussion of these subjects; you will find more detail in later chapters.

You are now ready to go on to Chapter 3 which deals with a description of the basic elements of the wastewater collection and treatment systems. Chapter 3 actually begins the discussion of *HOW* to treat wastewater. Chapter 2 has told you *WHY* you need to do so.

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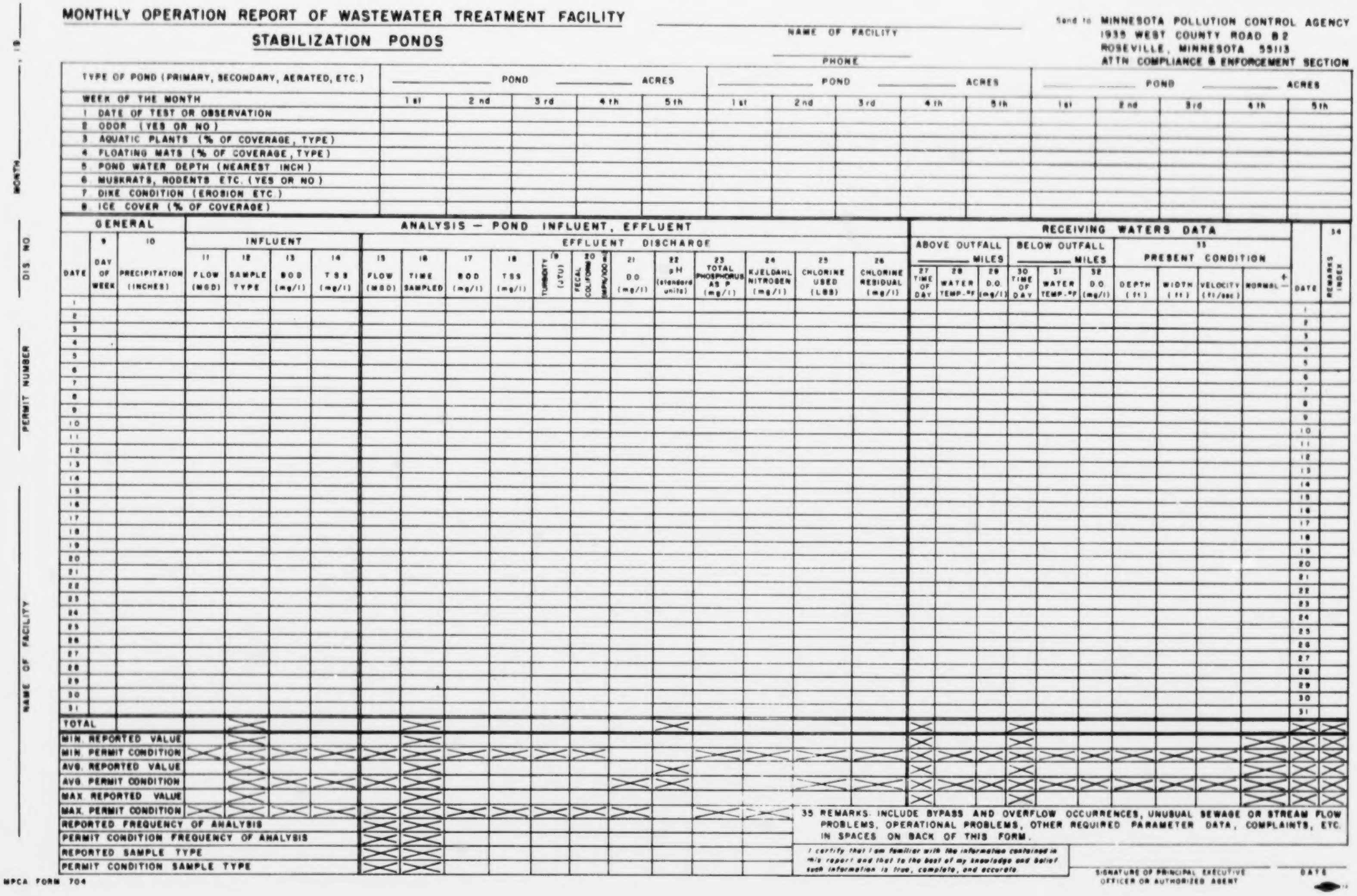
[19] *Septic (SEP-tick). This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.*

[20] *Biochemical Oxygen Demand (BOD). The rate at which microorganisms use oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.*

[21] *Coliform (COAL-i-form). One type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes other environmental sources.*



MONTHLY OPERATION REPORT OF WASTEWATER TREATMENT FACILITY

STABILIZATION PONDS

____
NAME OF FACILITY

____
PHONE

Send to MINNESOTA POLLUTION CONTROL AGENCY
1935 WEST COUNTY ROAD B2
ROSEVILLE, MINNESOTA 55113
ATTN COMPLIANCE & ENFORCEMENT SECTION

MONTH ________ , 19__

DIS NO ________

PERMIT NUMBER ________

NAME OF FACILITY ________

TYPE OF POND (PRIMARY, SECONDARY, AERATED, ETC.)	______ POND ______ ACRES					______ POND ______ ACRES					______ POND ______ ACRES				
WEEK OF THE MONTH	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
1 DATE OF TEST OR OBSERVATION															
2 ODOR (YES OR NO)															
3 AQUATIC PLANTS (% OF COVERAGE, TYPE)															
4 FLOATING MATS (% OF COVERAGE, TYPE)															
5 POND WATER DEPTH (NEAREST INCH)															
6 MUSKRATS, RODENTS ETC. (YES OR NO)															
7 DIKE CONDITION (EROSION ETC.)															
8 ICE COVER (% OF COVERAGE)															

GENERAL			ANALYSIS — POND INFLUENT, EFFLUENT																RECEIVING WATERS DATA											34
	9	10	INFLUENT				EFFLUENT DISCHARGE												ABOVE OUTFALL ______ MILES			BELOW OUTFALL ______ MILES			33 PRESENT CONDITION					
DATE	DAY OF WEEK	PRECIPITATION (INCHES)	11 FLOW (MGD)	12 SAMPLE TYPE	13 BOD (mg/l)	14 TSS (mg/l)	15 FLOW (MGD)	16 TIME SAMPLED	17 BOD (mg/l)	18 TSS (mg/l)	19 TURBIDITY (JTU)	20 FECAL COLIFORM (MPN/100 ml)	21 DO (mg/l)	22 pH (standard units)	23 TOTAL PHOSPHORUS AS P (mg/l)	24 KJELDAHL NITROGEN (mg/l)	25 CHLORINE USED (LBS)	26 CHLORINE RESIDUAL (mg/l)	27 TIME OF DAY	28 WATER TEMP-°F	29 D.O. (mg/l)	30 TIME OF DAY	31 WATER TEMP-°F	32 D.O. (mg/l)	DEPTH (ft)	WIDTH (ft)	VELOCITY (ft/sec)	NORMAL +/−	DATE	REMARKS INDEX
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31																													31	
TOTAL				☒				☒						☒					☒			☒							☒	☒
MIN. REPORTED VALUE				☒				☒											☒			☒						☒	☒	☒
MIN. PERMIT CONDITION			☒	☒	☒	☒	☒	☒	☒	☒	☒	☒			☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
AVG. REPORTED VALUE				☒				☒						☒					☒			☒						☒	☒	☒
AVG. PERMIT CONDITION				☒	☒	☒	☒	☒					☒	☒			☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
MAX. REPORTED VALUE				☒				☒											☒			☒						☒	☒	☒
MAX. PERMIT CONDITION			☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒		☒	☒														
REPORTED FREQUENCY OF ANALYSIS							☒	☒																						
PERMIT CONDITION FREQUENCY OF ANALYSIS							☒	☒																						
REPORTED SAMPLE TYPE							☒	☒																						
PERMIT CONDITION SAMPLE TYPE							☒	☒																						

35 REMARKS: INCLUDE BYPASS AND OVERFLOW OCCURRENCES, UNUSUAL SEWAGE OR STREAM FLOW PROBLEMS, OPERATIONAL PROBLEMS, OTHER REQUIRED PARAMETER DATA, COMPLAINTS, ETC. IN SPACES ON BACK OF THIS FORM.

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief such information is true, complete, and accurate.

____
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT

____
DATE

MPCA FORM 704

Fig. 2.3 Typical NPDES permit reporting form

Operators of wastewater treatment plants operate their plants with the objectives of providing the best possible treatment of wastes to protect the receiving waters, downstream users, and neighbors. They accomplish these objectives by

1. Removing wastes from the wastewater to protect the receiving waters regardless of other problems or impacts of protective action in their plant,
2. Meeting NPDES Permit requirements,
3. Minimizing odors to avoid nuisance complaints,
4. Minimizing costs,
5. Minimizing energy consumption, and
6. Maintaining an effective preventive maintenance program.

The remaining chapters in this manual were prepared for you by operators with the intent of providing you with the knowledge and skills necessary to be a wastewater treatment plant operator.

SUGGESTED ANSWERS

Chapter 2. WHY TREAT WASTES?

Answers to questions on page 16.

2.1A Some of the dissolved substances in water include oxygen, calcium, carbon, magnesium, chloride, sodium, sulfate, iron, nitrogen, phosphorus, and organic material.

2.1B Water picks up dissolved substances as it falls as rain, flows over land and is used for domestic, industrial, agricultural, and recreational purposes.

Answers to questions on page 17.

2.2A a, c, and e.

2.2B Organic, inorganic, thermal, radioactive.

Answers to questions on page 18.

2.3A Organic wastes in water provide food for the bacteria. These bacteria require oxygen to survive and consequently deplete the oxygen in the water in a way similar to the way oxygen is removed from air when people breathe.

2.3B Hydrogen sulfide gas is produced by anaerobic bacteria.

Answers to questions on page 18.

2.3C Disease-causing bacteria in wastewater come from the body wastes of humans who have a disease.

2.3D Pathogenic.

2.3E Chlorination is the most frequent means of disinfecting treated wastewater.

Answers to questions on page 20.

2.4A Settleable.

2.4B Settleable solids must be measured to determine the efficiency of settling basins. This amount must also be known to calculate loads on settling basins, sludge pumps, and sludge handling facilities for design and operational purposes. You should have recognized the need to know the efficiency of settling basins.

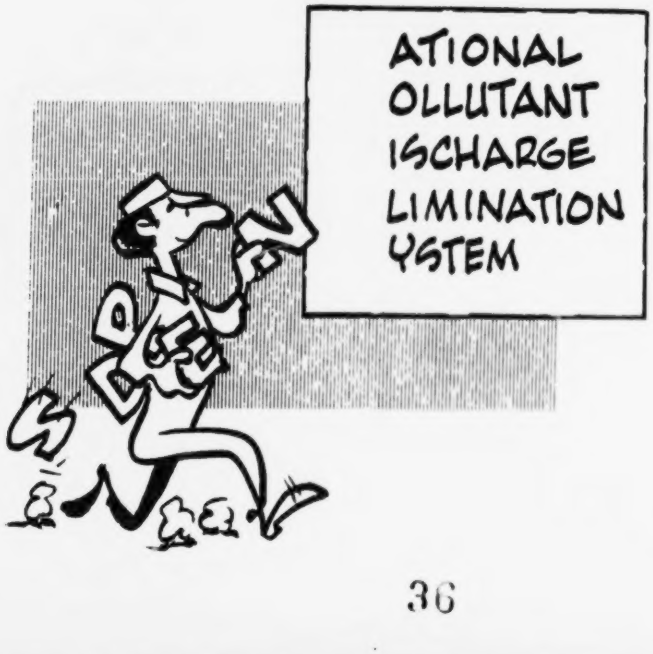
2.4C *DISSOLVED* and *SUSPENDED* solids.

Answers to questions on page 21.

2.5A Operators need an understanding of natural cycles in order to control wastewater treatment processes and odors and also to protect receiving waters.

2.5B When nutrient cycles become disrupted and there is no dissolved oxygen in the receiving water, these waters become septic, stink and look terrible.

2.6A NPDES stands for **N**ational **P**ollutant **D**ischarge **E**limination **S**ystem.



OBJECTIVE TEST

Chapter 2. WHY TREAT WASTES?

Please mark correct answers in the proper columns on the answer sheet, as directed at the end of Chapter 1. Return your answer sheet to your project Director.

1. Wastes are treated to do which of the following?
   1. Prevent pollution
   2. Prevent receiving waters from stinking
   3. Protect human health
   4. Remove harmful wastes from wastewater

2. Diseases possibly spread by wastewater discharges include
   1. Cholera.
   2. Dysentery.
   3. Hepatitis. (Jaundice)
   4. Q Fever.
   5. Typhoid.

3. Pathogenic bacteria are
   1. Disease causing.
   2. Dissolved gases.
   3. Easy to see.
   4. Inorganic.
   5. None of these.

4. What does an Imhoff Cone measure?
   1. Colloidal Solids
   2. Dissolved Solids
   3. Organic Solids
   4. Settleable Solids
   5. Total Solids

Match the definitions on the following page by placing the correct number from the column on the right in the proper space in front of the definition.

EXAMPLE

2 Milligrams per liter.	1. MPL 2. mg/*L* 3. MPN

Mark Column 2 on your answer sheet:

---

5. ______ Bacteria which obtain their oxygen by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4).

6. ______ Bacteria which will live and reproduce only in an environment containing atmospheric oxygen or oxygen dissolved in water.

7. ______ Waste material which comes from animal or vegetable sources.

1. Aerobic Bacteria
2. Anaerobic Bacteria
3. Inorganic Waste
4. Organic Waste
5. Radioactive

---

8. ______ A process which kills disease-causing bacteria.

9. ______ Any discharge of waste that reduces receiving water quality indicators below the established water quality standards.

10. ______ Bacteria which can cause disease.

1. Disinfection
2. Nutrients
3. Pathogenic Bacteria
4. pH
5. Pollution

11. Natural cycles could refer to which of the following?
    1. Effluent cycles
    2. Life cycles of aquatic organisms
    3. Natural purification cycles
    4. Nutrient cycles
    5. Sludge cycles

12. Effluent limitations that may be specified in an NPDES permit include
    1. Acceptable range of pH values.
    2. Biochemical oxygen demand (BOD)
    3. Most probable number (MPN) of coliform group bacteria.
    4. Suspended solids (nonfilterable residue)
    5. Toxic substances.

END OF OBJECTIVE TEST

CHAPTER 3

WASTEWATER TREATMENT FACILITIES

by

John Brady

and

William Crooks

TABLE OF CONTENTS

Chapter 3. Wastewater Treatment Facilities

Page

GLOSSARY 27

3.0 Collection, Treatment, Disposal 29

3.1 Collection of Wastewater 29

3.10 Sanitary, Storm, and Combined Sewers 29

3.2 Treatment Plants 30

3.3 Pretreatment 37

3.30 Purpose 37

3.31 Screening 37

3.32 Shredding 38

3.33 Grit Chambers or Grit Channels 38

3.4 Flow-Measuring Devices 38

3.5 Primary Treatment 39

3.6 Secondary Treatment 42

3.60 Purpose 42

3.61 Trickling Filter 42

3.62 Rotating Biological Contactors 42

3.63 Activated Sludge 42

3.64 Secondary Clarifiers 43

3.7 Solids Handling and Disposal 45

3.70 Purpose 45

3.71 Digestion and Dewatering 45

3.72 Incineration 45

3.8 Waste Treatment Ponds 49

3.9 Advanced Methods of Treating Wastewater 49

3.10 Disinfection 50

3.11 Effluent Disposal 50

3.12 Solids Disposal 50

3.13 Arithmetic Assignment 51

3.14 Additional Reading 51

GLOSSARY

Chapter 3. WASTEWATER TREATMENT FACILITIES

BIOCHEMICAL OXYGEN DEMAND (BOD) BIOCHEMICAL OXYGEN DEMAND

The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BIOCHEMICAL OXYGEN DEMAND (BOD) TEST BIOCHEMICAL OXYGEN DEMAND (BOD)TEST

A procedure that measures the rate of oxygen use under controlled conditions of time and temperature. Standard test conditions include dark incubation at 20°C for a specified time (usually five days).

COMBINED SEWER COMBINED SEWER

A sewer designed to carry both sanitary wastewaters and storm- or surface-water runoff.

COMMINUTION (com-mi-NEW-shun) COMMINUTION

Shredding. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment. *COMMINUTION* and *SHREDDING* usually mean the same thing.

DETENTION TIME DETENTION TIME

The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DEWATER DEWATER

To remove or separate a portion of the water present in a sludge or slurry.

EFFLUENT (EF-lu-ent) EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

FACULTATIVE POND (FACK-ul-TAY-tive) FACULTATIVE POND

The most common type of pond in current use. The upper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.

GRIT GRIT

The heavy mineral material present in wastewater, such as sand, gravel, cinders, and eggshells.

HEADWORKS HEADWORKS

The facilities where wastewater enters a wastewater treatment plant. The headworks may consist of bar screens, comminutors, a wet well and pumps.

INFILTRATION (IN-fill-TRAY-shun) INFILTRATION

The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.

INFLOW INFLOW

Water discharged into the sewer system from sources other than regular connections. This includes flow from yard drains, foundations and around manhole covers. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.

INFLUENT (IN-flu-ent) INFLUENT

Wastewater or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process, or treatment plant.

MEDIA MEDIA

The material in a trickling filter on which slime organisms grow. As settled wastewater trickles over the media, slime organisms remove certain types of wastes thereby partially treating the wastewater. Also the material in a rotating biological contactor or in a gravity or pressure filter.

PHOTOSYNTHESIS (foto-SIN-tha-sis) PHOTOSYNTHESIS

A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. All green plants grow by this process.

PRIMARY TREATMENT PRIMARY TREATMENT

A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

SANITARY SEWER (SAN-eh-tare-ee SUE-er) SANITARY SEWER

A sewer intended to carry wastewater from homes, businesses, and industries. Storm water runoff should be collected and transported in a separate system of pipes.

SECONDARY TREATMENT SECONDARY TREATMENT

A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

SHREDDING SHREDDING

Comminution. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment. *SHREDDING* and *COMMINUTION* usually mean the same thing.

SLUDGE (sluj) SLUDGE

The settleable solids separated from liquids during processing or the deposits of foreign materials on bottoms of streams or other bodies of water.

STORM SEWER STORM SEWER

A separate sewer that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes.

SUPERNATANT (sue-per-NAY-tent) SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.

WEIR (weer) WEIR

(1) A wall or plate placed in an open channel and used to measure the flow. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

WET OXIDATION WET OXIDATION

A method of treating or conditioning sludge before the water is removed. Compressed air is blown into the liquid sludge. The air and sludge mixture is fed into a pressure vessel where the organic material is stabilized. The stabilized organic material and inert (inorganic) solids are then separated from the pressure vessel effluent by dewatering in lagoons or by mechanical means.

WET WELL WET WELL

A compartment or room in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

CHAPTER 3. WASTEWATER TREATMENT FACILITIES

3.0 COLLECTION, TREATMENT, DISPOSAL

Facilities for handling wastewater are usually considered to have three major components or parts: collection, treatment, and disposal. For a municipality, these components make up the wastewater facilities; but for an individual industry which handles its own wastewater, the same three components are necessary. This training course is directed primarily to plant operators for municipalities, so the discussion in this and later chapters will be in terms of municipal wastewater treatment facilities. Treatment of industrial wastes is discussed in Chapter 28.

3.1 COLLECTION OF WASTEWATER

Collection and transportation of wastewater to the treatment plant is accomplished through a complex network of pipes and pumps of many sizes.

Major water-using industries which contribute waste to the collection system may affect the efficiency of a wastewater treatment plant, especially if there are periods during the day or during the year when these industrial waste flows are a major load on the plant. For instance, canneries are highly seasonal in their operations; therefore, it is possible to predict the time of year to expect large flows from them. A knowledge of the location, amount, and types of wastes from commercial and industrial dischargers in the collection system may enable an operator to locate the source of a problem in the plant *INFLUENT*,[1] such as oil from a refinery or a gas station.

The length of time required for wastes to reach your plant can also affect treatment plant efficiency. Hydrogen sulfide gas (rotten egg gas) may be released by anaerobic bacteria feeding on the wastes if the flow time is quite long and the weather is hot; this can cause odor problems, damage concrete in your plant, and make the wastes more difficult to treat. (Solids won't settle easily, for instance.) Wastes from isolated subdivisions located far away from the main collection network often have this "aging" problem.

3.10 Sanitary, Storm, and Combined Sewers

For most sewerage systems, the sewer coming into the treatment plant carries wastes from households and commercial establishments in the city or district, and possibly some industrial wastes. This type of sewer is called a *SANITARY SEWER*.[2] All storm runoff from streets, land, and roofs of buildings is collected separately in a *STORM SEWER*,[3] which normally discharges to a water course without treatment. In some areas only one network of sewers has been laid out beneath the city to pick up both sanitary wastes and storm water in a *COMBINED SEWER*.[4] Treatment plants that are designed to handle the sanitary portion of the wastes sometimes must be bypassed during storms due to inadequate capacity, allowing untreated wastes to be discharged into receiving waters. Separation of combined sewers into sanitary and storm sewers is very costly and difficult to accomplish.

Even in areas where the sanitary and storm sewers are separate, *INFILTRATION*[5] of groundwater or storm water into sanitary sewers through breaks or open joints can cause high flow problems at the treatment plant. Replacement or sealing of leaky sections of sewer pipe is called for in these cases. The

Fig. 3.1 Manholes allow inspection of the collection system

---

[1] *Influent (IN-flu-ent). Wastewater or other liquid – raw or partly treated – flowing* INTO *a reservoir, basin, treatment process, or treatment plant.*

[2] *Sanitary Sewer (SAN-eh-tare-ee SUE-er). A sewer intended to carry wastewater from homes, businesses, and industries. Storm water runoff should be collected and transported in a separate system of pipes.*

[3] *Storm Sewer. A separate sewer that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes.*

[4] *Combined Sewer. A sewer designed to carry both sanitary wastewaters and storm- or surface-water runoff.*

[5] *Infiltration (IN-fill-TRAY-shun). The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.*

treatment plant operator is generally the first to know about infiltration problems because of the unusually high flows observed at the plant during periods of storm water runoff.

Sanitary sewers are normally placed at a slope sufficient to produce a water velocity (speed) of approximately two feet per second when flowing full. This velocity will usually prevent the deposition of solids that may clog the pipe or cause odors. Manholes are placed every 300 to 500 feet to allow for inspection and cleaning of the sewer.

When low areas of land must be sewered or where pipe depth under the ground surface becomes excessive, pump stations (Fig. 3.2) are normally installed. These pump stations lift the wastewater to a higher point from which it may again flow by gravity, or the wastewater may be pumped under pressure directly to the treatment plant. A large pump station located just ahead of the treatment plant can create problems by periodically sending large volumes of flow to the plant one minute, and virtually nothing the next minute. These fluctuating *flows can be reduced by using variable speed pumps or short pumping cycles.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 52.

3.1A Why should the operator be familiar with the wastewater collection and transportation network?

3.1B List three types of sewers.

3.1C What problem may occur when it takes a long time for wastewater to flow through the collection sewers to the treatment plant?

3.1D Why are combined sewers a problem?

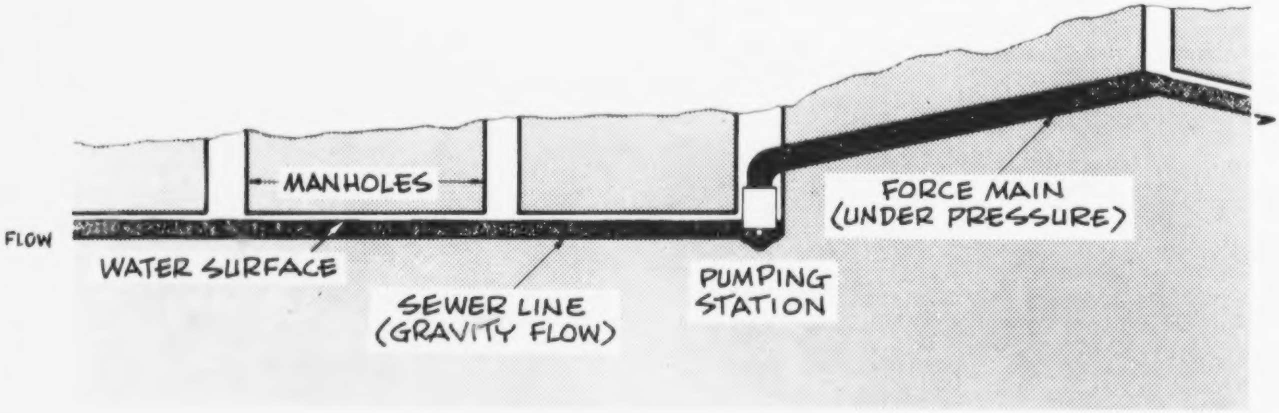


Fig. 3.2 Collection sewer profile

3.2 TREATMENT PLANTS

Upon reaching a wastewater treatment plant, the wastewater flows through a series of treatment processes (Fig. 3.3) which remove the wastes from the water and reduce its threat to the public health before it is discharged from the plant. The number of treatment processes and the degree of treatment usually depend on the uses of the receiving waters. Treated wastewaters discharged into a small stream used for a domestic water supply and swimming will require considerably more treatment than wastewater discharged into water used solely for navigation.

To provide you with a general picture of treatment plants, the remainder of this chapter will follow the paths wastewater might travel as it passes through a plant. You will be introduced to the names of the treatment processes, the kinds of wastes the processes treat or remove, and the location of the processes in the flow path. Not all treatment plants are alike; however, there are certain typical flow patterns that are similar from one plant to another. Figures 3.4, 3.5, and 3.6 show some possible flow patterns through treatment plants.

When wastewater enters a treatment plant, it usually flows through a series of pretreatment processes — screening, shredding, and grit removal. These processes remove the coarse material from the wastewater. Flow-measuring devices are usually installed after pretreatment processes to record the flow rates and volumes of wastewater treated by the plant.

Next the wastewater will generally receive primary treatment. During primary treatment, some of the solid matter carried by the wastewater will settle out or float to the water surface where it can be separated from the wastewater being treated.

Secondary treatment processes usually follow primary treatment and commonly consist of biological processes. This means that organisms living in the controlled environment of the process are used to partially stabilize (oxidize) organic matter not removed by previous treatment processes and to convert it into a form which is easier to remove from the wastewater.

Waste material removed by the treatment processes goes to solids handling facilities and then to ultimate disposal.

Waste treatment ponds may be used to treat wastes remaining in wastewater after pretreatment, primary treatment, or secondary treatment. Ponds are frequently constructed in rural areas where there is sufficient available land.

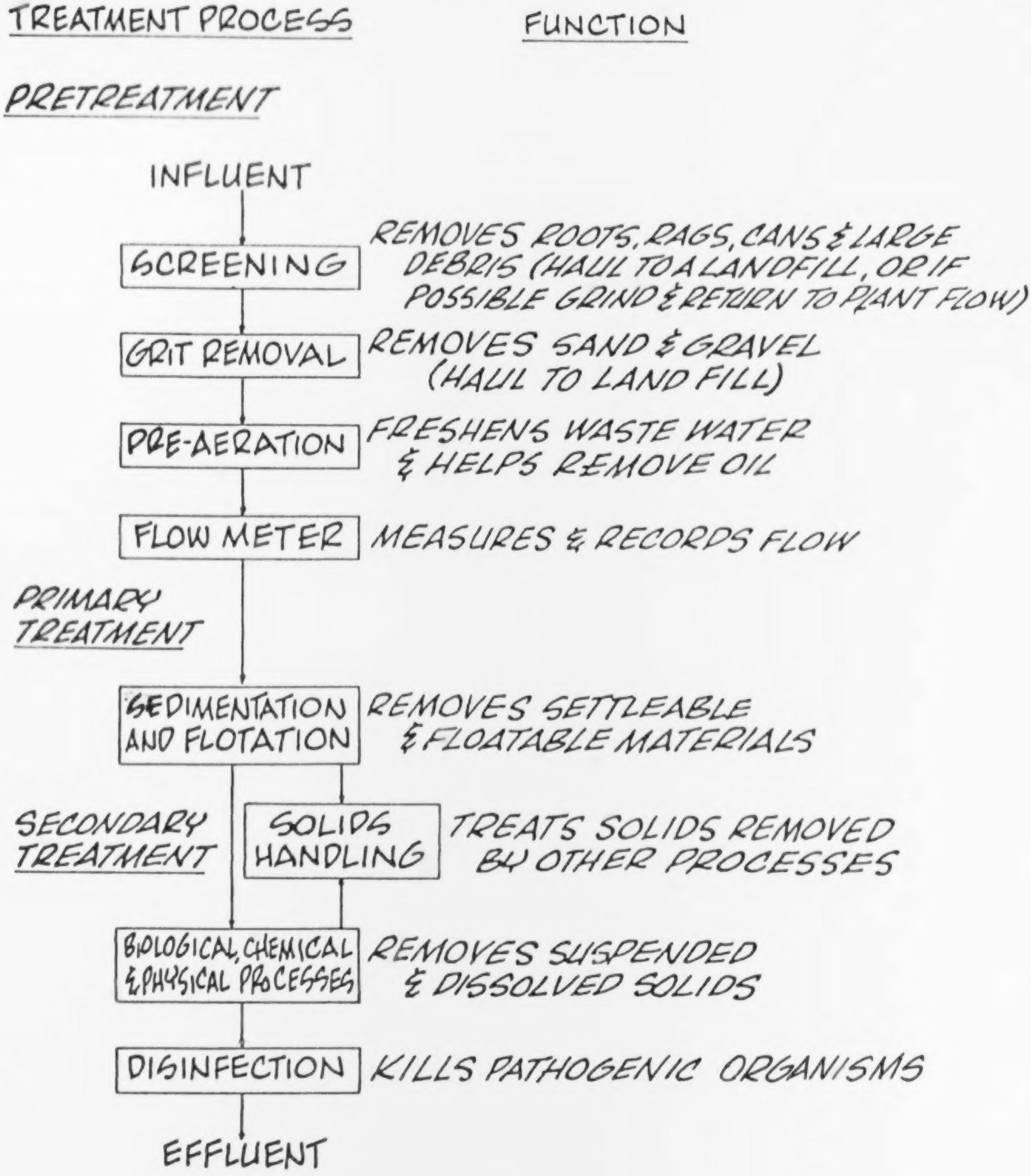

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
BIOLOGICAL, CHEMICAL & PHYSICAL PROCESSES
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
EFFLUENT

Fig. 3.3 Flow diagram of wastewater treatment plant processes

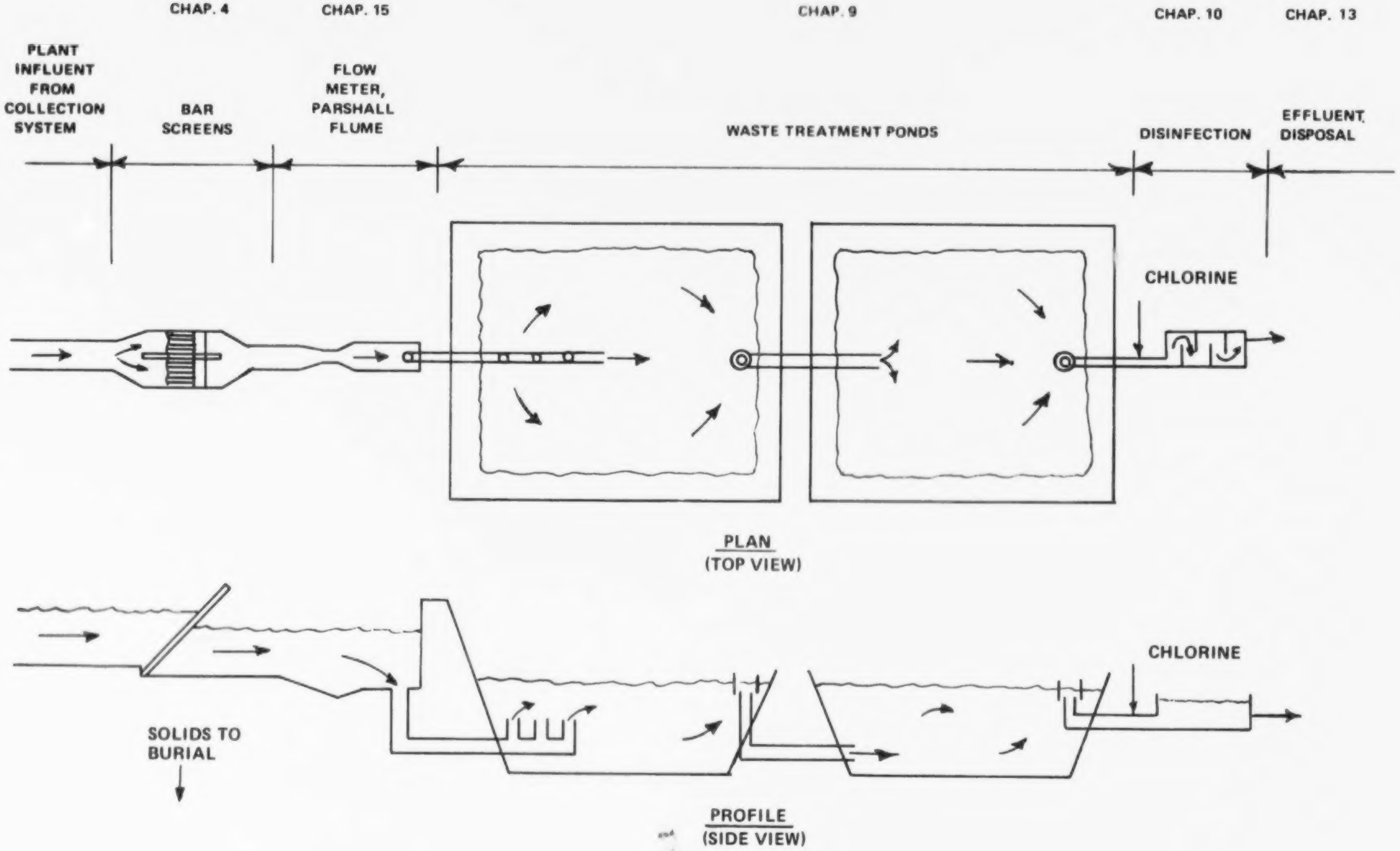
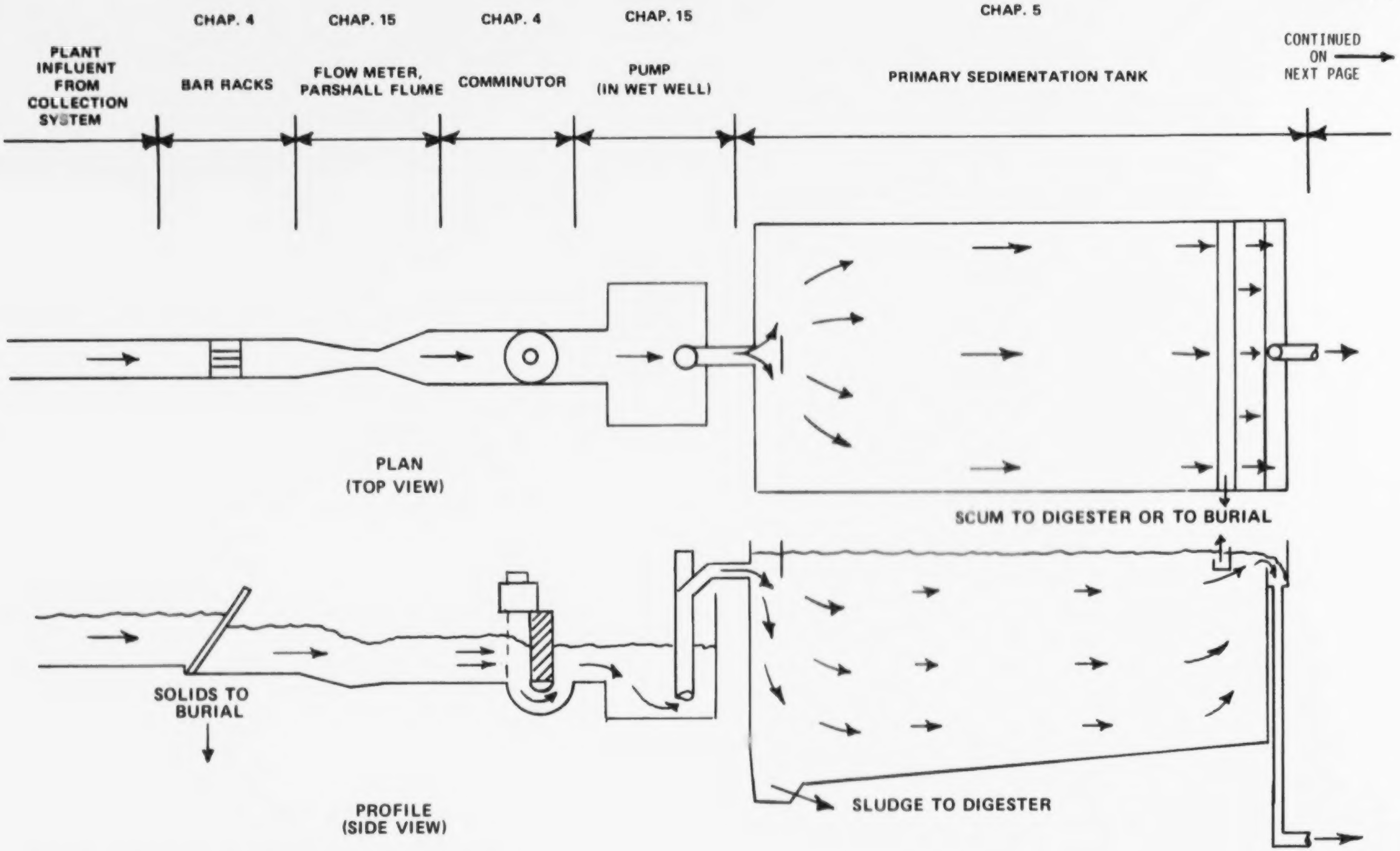

CHAP. 4
CHAP. 15
CHAP. 9
CHAP. 10
CHAP. 13
PLANT INFLUENT FROM COLLECTION SYSTEM
BAR SCREENS
FLOW METER, PARSHALL FLUME
WASTE TREATMENT PONDS
DISINFECTION
EFFLUENT DISPOSAL
CHLORINE
PLAN (TOP VIEW)
CHLORINE
SOLIDS TO BURIAL
PROFILE (SIDE VIEW)

Fig. 3.4 Possible flow pattern through a pond treatment plant


CHAP. 4
CHAP. 15
CHAP. 4
CHAP. 15
CHAP. 5
PLANT INFLUENT FROM COLLECTION SYSTEM
BAR RACKS
FLOW METER, PARSHALL FLUME
COMMINUTOR
PUMP (IN WET WELL)
PRIMARY SEDIMENTATION TANK
CONTINUED ON NEXT PAGE
PLAN (TOP VIEW)
SCUM TO DIGESTER OR TO BURIAL
SOLIDS TO BURIAL
PROFILE (SIDE VIEW)
SLUDGE TO DIGESTER

NOTE: SOLIDS FLOW NOT SHOWN, SEE SECTION 3.7

Fig. 3.5 Possible flow pattern through a trickling filter plant

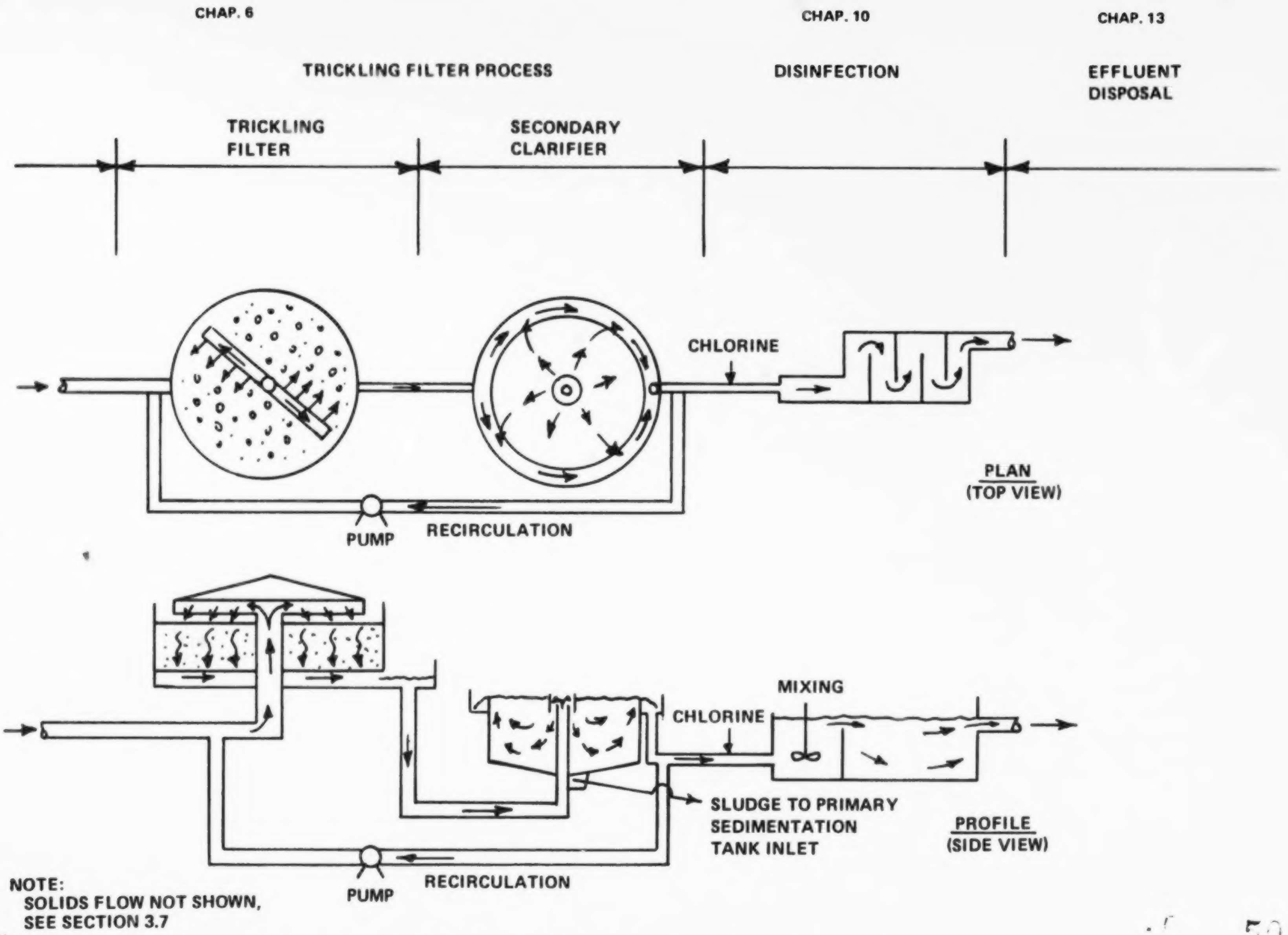
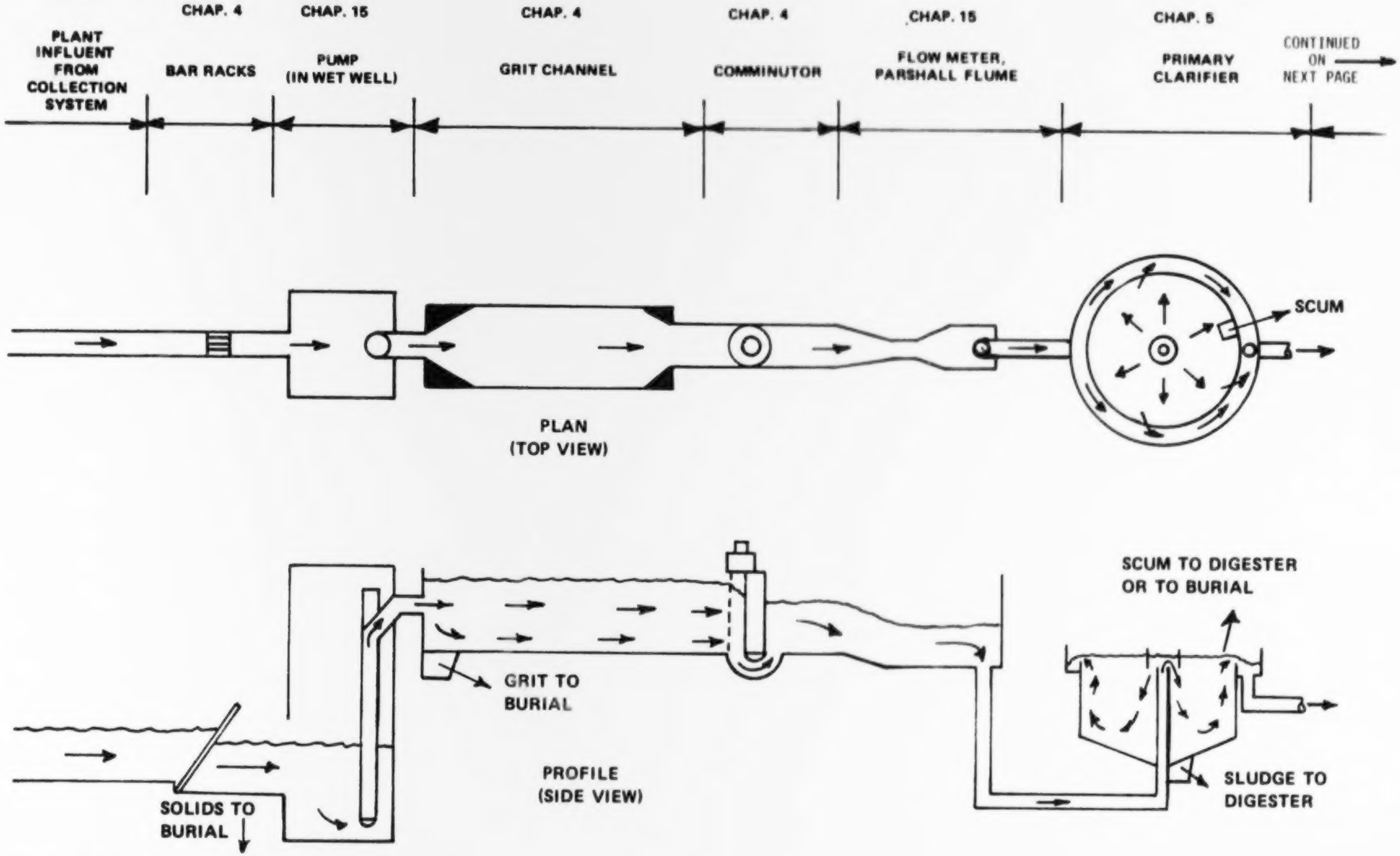
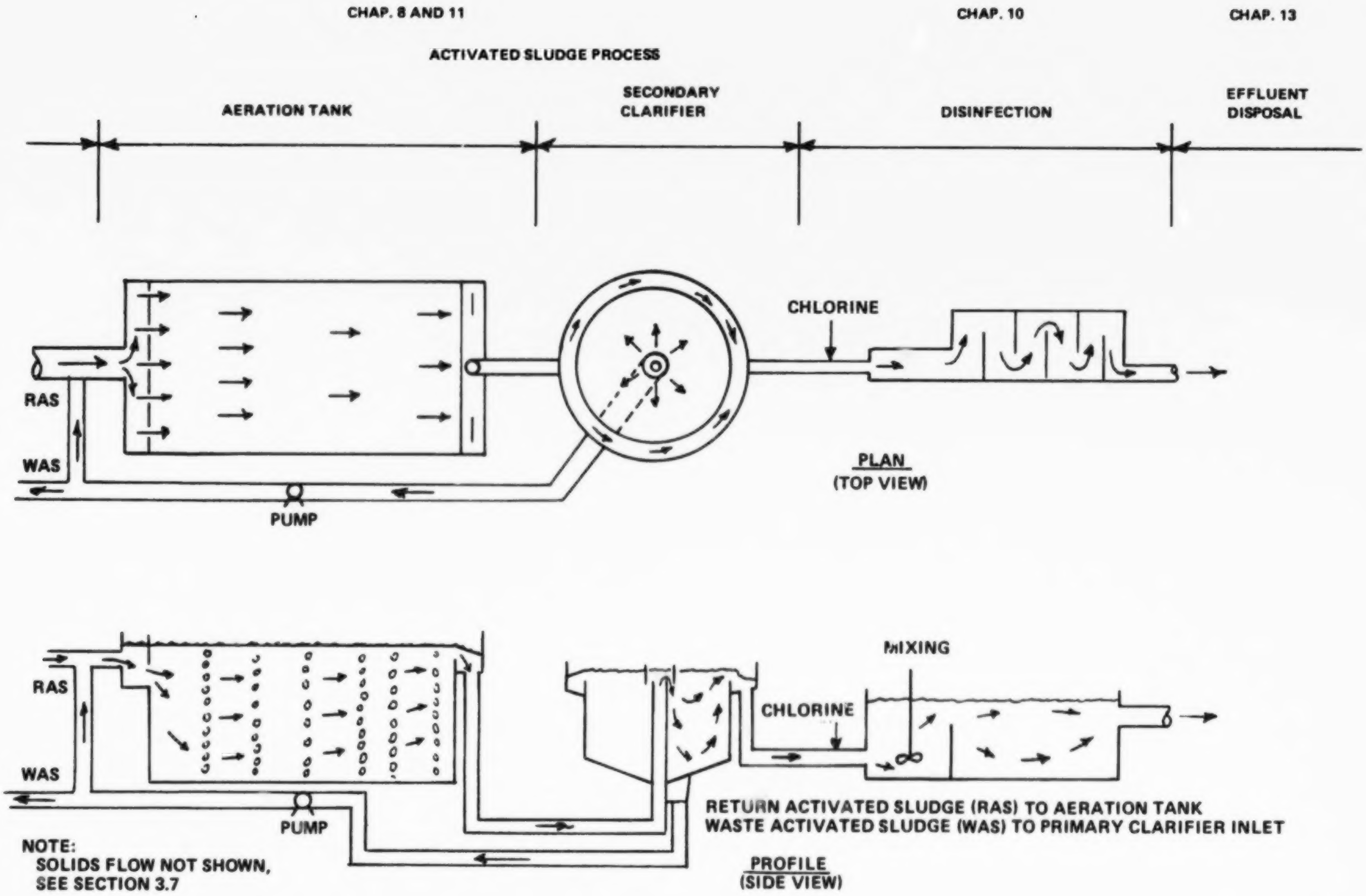

CHAP. 6
CHAP. 10
CHAP. 13
TRICKLING FILTER PROCESS
DISINFECTION
EFFLUENT DISPOSAL
TRICKLING FILTER
SECONDARY CLARIFIER
CHLORINE
PUMP
RECIRCULATION
PLAN (TOP VIEW)
MIXING
CHLORINE
SLUDGE TO PRIMARY SEDIMENTATION TANK INLET
PROFILE (SIDE VIEW)
PUMP
RECIRCULATION
NOTE:
SOLIDS FLOW NOT SHOWN, SEE SECTION 3.7

Fig. 3.5 (Con'd) Possible flow pattern through a trickling filter plant


CHAP. 4
CHAP. 15
CHAP. 4
CHAP. 4
CHAP. 15
CHAP. 5
PLANT INFLUENT FROM COLLECTION SYSTEM
BAR RACKS
PUMP (IN WET WELL)
GRIT CHANNEL
COMMINUTOR
FLOW METER, PARSHALL FLUME
PRIMARY CLARIFIER
CONTINUED ON NEXT PAGE
SCUM
PLAN (TOP VIEW)
SCUM TO DIGESTER OR TO BURIAL
GRIT TO BURIAL
PROFILE (SIDE VIEW)
SOLIDS TO BURIAL
SLUDGE TO DIGESTER

NOTE: SOLIDS FLOW NOT SHOWN, SEE SECTION 3.7

Fig. 3.6 Possible flow pattern through an activated sludge plant


CHAP. 8 AND 11
ACTIVATED SLUDGE PROCESS
CHAP. 10
CHAP. 13
AERATION TANK
SECONDARY CLARIFIER
DISINFECTION
EFFLUENT DISPOSAL
CHLORINE
RAS
WAS
PUMP
PLAN
(TOP VIEW)
MIXING
RAS
CHLORINE
WAS
PUMP
PROFILE
(SIDE VIEW)

RETURN ACTIVATED SLUDGE (RAS) TO AERATION TANK
WASTE ACTIVATED SLUDGE (WAS) TO PRIMARY CLARIFIER INLET

NOTE:
SOLIDS FLOW NOT SHOWN,
SEE SECTION 3.7

Fig. 3.6 (Con'd) Possible flow pattern through an activated sludge plant

Advanced methods of waste treatment are being developed for general cleanup of wastewater or removal of substances not removed by conventional treatment processes. They may follow the treatment processes previously described, or they may be used instead of them.

Before treated wastewater is discharged to the receiving waters, it should be disinfected to prevent the spread of disease. Chlorine is usually added for disinfection purposes. After the chlorine contact basin, sulfur dioxide (SO_2) may be added to the *EFFLUENT*[6] to neutralize the chlorine and thus detoxify the effluent.

In the following sections these treatment processes will be briefly discussed to provide an overall concept of a treatment plant. Details will be presented in later chapters to provide complete information on each of these processes.

3.3 PRETREATMENT (Chapter 4)

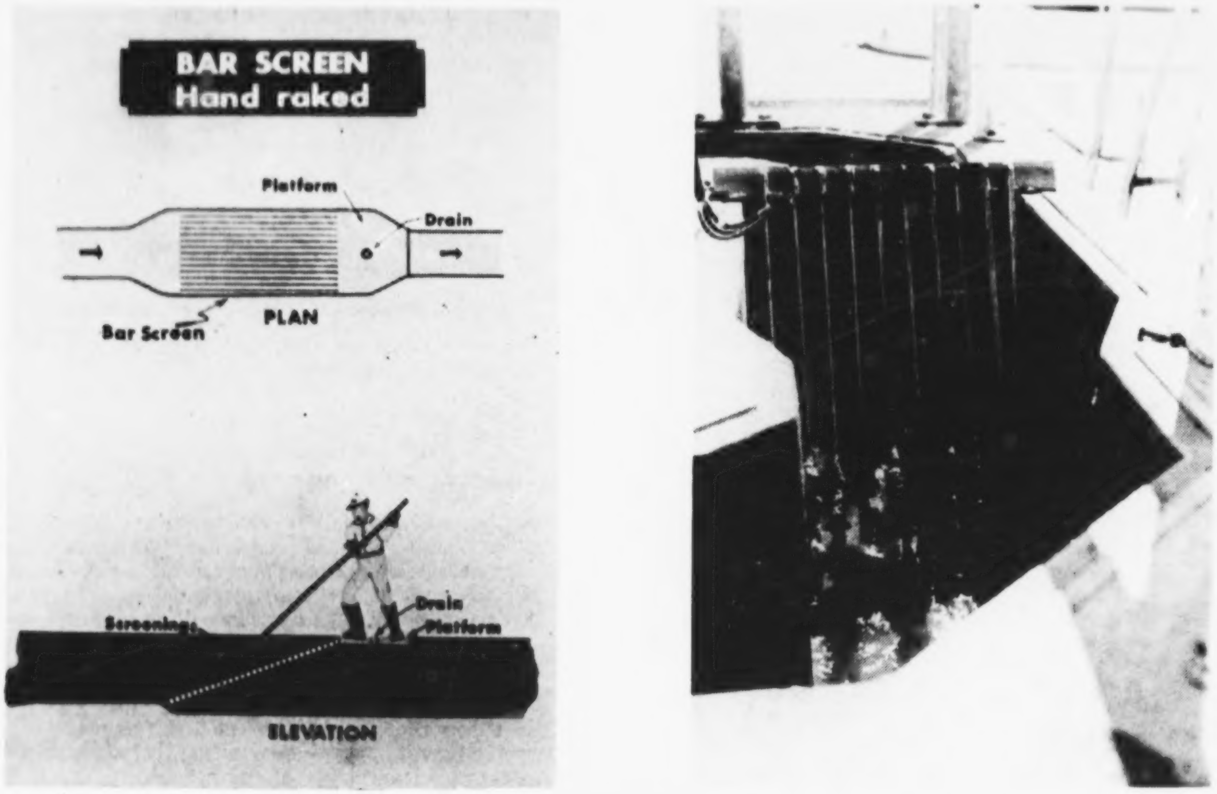
3.30 Purpose

Pretreatment processes commonly consist of screening (Fig. 3.7), *SHREDDING*,[7] and grit removal to separate coarse material from the wastewater being treated.

Fig. 3.7 Screened & ground

3.31 Screening

Wastewater flowing into the treatment plant will occasionally contain pieces of wood, roots, rags, and other debris. To protect equipment and reduce any interference with in-plant flow, debris and trash are usually removed by a bar screen (Fig. 3.8). Most screens in treatment plants consist of parallel bars placed at an angle in a channel in such a manner that the wastewater flows through the bars. Trash collects on the bars and is periodically raked off by hand or by mechanical means. In most plants these screenings are disposed of by burying or burning. In some cases they are automatically ground and returned to the wastewater flow for removal by a later process.



(Courtesy Water Pollution Control Federation)

Fig. 3.8 Bar screens

---

[6] *Effluent (EF-lu-ent). Wastewater or other liquid – raw, partially or completely treated – flowing* FROM *a basin, treatment process, or treatment plant.*

[7] *Shredding. Comminution. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment.* SHREDDING *and* COMMINUTION *usually mean the same thing.*

3.32 Shredding

Devices are also available which cut up or shred material while it remains in the wastewater stream. The most common of these are the barminutor (Fig. 3.9) and the comminutor (Fig. 3.10). One of these devices usually follows a bar screen.

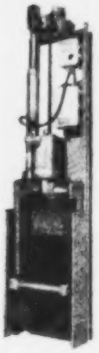


Fig. 3.9 Barminutor

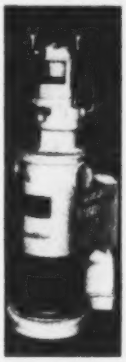


Fig. 3.10 Comminutor

(Courtesy Chicago Pump)

3.33 Grit Chambers or Grit Channels

Most sewer pipes are laid at a slope steep enough to maintain a wastewater flow of two feet per second (fps). If the velocity is reduced slightly below that, say to 1.5 fps, some of the larger, heavier particles will settle out. If the velocity is reduced to about 1 fps, heavy inorganic material such as sand, eggshells, and cinders will settle; but the lighter organic material will remain in suspension. The settled inorganic material is referred to as *GRIT*.[8] Grit should be removed (Fig. 3.11) early in the treatment process because it is abrasive and will rapidly wear out pumps and other equipment. Since it is mostly inorganic, it cannot be broken down by any biological treatment process and thus should be removed as soon as possible.

Grit is usually removed in a long, narrow trough called a "grit channel" (Fig. 3.12). A grit channel is designed to provide a flow-through velocity of 1 fps. The settled grit may be removed either manually or mechanically. Since there is normally some organic solid material deposited along with the grit, it is usually buried to avoid nuisance conditions. Some plants are equipped with "grit washers" that remove some of the organic material from the grit so that organic solids can remain in the main waste flow to be treated.

Fig. 3.11 Removal of eggshells (Don't remove grit with your bare hands)

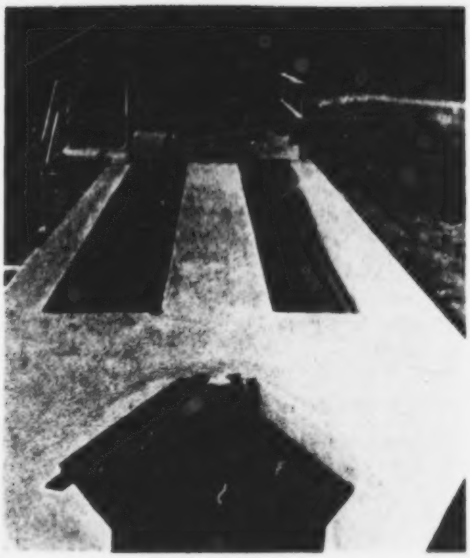


Fig. 3.12 Grit channel

WPCF MOP No. 11

Operation of Wastewater Treatment Plants

Many treatment plants have aerated grit chambers in which compressed air is added through diffusers to provide better separation of grit and other solids. Aeration in this manner also "freshens" a "stale" or septic wastewater, helping to prevent odors and to assist the biological treatment process.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 52.

3.3A Why is grit removed early in the treatment process?

3.3B What is usually done with grit which has been removed from the wastewater?

3.4 FLOW-MEASURING DEVICES

Although flow-measuring devices are not for *TREATING* wastes, it is necessary to know the quantity of wastewater flow so adjustments can be made on pumping rates, chlorination rates, aeration rates, and other processes in the plant. Flow rates must be known, also, for calculation of loadings on treatment processes and treatment efficiency. Most operators prefer to have a measuring device at the *HEADWORKS*[9] of their treatment plant.

The most common measuring device is a Parshall Flume. Basically it is a narrow place in an open channel which allows the quantity of flow to be determined by measuring the depth of flow. This method is widely used for measuring wastewater because its smooth constriction does not offer any protruding sharp edges or areas where wastewater particles may catch or collect behind the metering device.

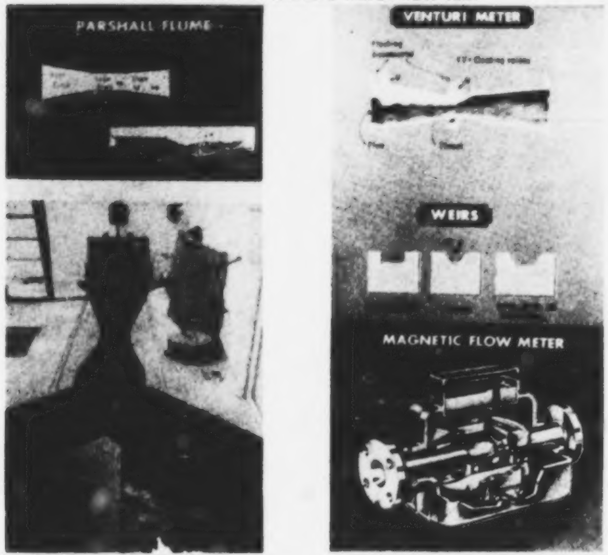
---

[8] *Grit. The heavy mineral present in wastewater, such as sand, gravel, cinders, and eggshells.*

[9] *Headworks. The facilities where wastewater enters a wastewater treatment plant. The headworks may consist of bar screens, comminutors, a wet well and pumps.*

Another measuring device used in open channels is a *WEIR*[10] (Fig. 3.13). The weir, which is placed across the channel, is a wall over which the wastewater may fall. Weirs are usually made of thin metal and may have either a rectangular or V-notch opening. The flow over the weir is determined by the depth of wastewater going through the opening. A disadvantage of a weir is the relatively dead water space that occurs just upstream of the weir. If the weir is used at the head end of the plant, organic solids may settle out in this area. When this occurs, odors and unsightliness can result. Also, as the solids accumulate, the flow reading may become incorrect.

NOTE: Venturi Meters must flow full.



End Photo of Parshall Flume

(Drawings courtesy of Water Pollution Control Federation)

Fig. 3.13 Flow meters

A good measuring device for flows of treated or untreated wastewater is a Venturi meter. This meter has a special section of contracting pipe, and it measures flow in much the same way as a Parshall Flume. There are no sharp obstructions to catch rags and debris. Magnetic flow meters also are being used successfully to measure wastewater flow.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 52.

3.4A Why are weirs not frequently used to measure the influent to a plant?

3.4B Why is a Parshall Flume widely used for measuring wastewater flow?

3.5 PRIMARY TREATMENT (Chapter 5)

We have previously discussed the reduction in velocity of the incoming waste to approximately one foot per second in order to settle out heavy inorganic material or grit. The next step in the treatment process is normally called *SEDIMENTATION* or *PRIMARY TREATMENT*. In this process the waste is directed into and through a large tank or basin. Flow velocity in these tanks is reduced to about 0.03 foot per second, allowing the settleable solids to fall to the bottom of the tank, thus making the wastewater much clearer. For this reason these sedimentation tanks are called "clarifiers." The first clarifier that the wastewater flows into is called a *PRIMARY* clarifier. We will discuss later the need for another clarifier after the biological treatment process. This second clarifier is called a "secondary clarifier."

Clarifiers normally are either rectangular (Fig. 3.14) or circular (Fig. 3.15). Primary clarifiers are usually designed to provide 1.5 to 2 hours *DETENTION TIME*.[11] Secondary clarifiers usually provide slightly more time.

Generally the longer the detention time, the greater the solids removal. In a tank with two hours detention time, approximately 60 percent of the suspended solids in the raw wastewater will either settle to the bottom or float to the surface and be removed. Removal of these solids will usually reduce the *BIOCHEMICAL OXYGEN DEMAND (BOD)*[12] of the waste approximately 30 percent. The exact removal depends on the amount of BOD contained in the settled material.

All primary clarifiers, no matter what their shape, must have a means for collecting the settled solids (called *SLUDGE*[13]) and the floating solids (called scum). In rectangular tanks sludge and scum collectors are usually wooden beams (flights) attached to endless chains. The collector flights travel on the surface, in the direction of the flow, conveying grease and floatable solids down to the scum trough to be skimmed off to the solids (sludge) handling facilities. The flights then drop below the surface and return to the influent end along the bottom, moving the settled raw sludge to the sludge hopper. The sludge is periodically pumped from the hopper to the sludge handling facilities.

In circular tanks, scrapers (plows) attached to a rotating arm rotate slowly around the bottom of the tank. The plows push the settled sludge toward the center and into the sludge hopper. Scum is collected by a rotating blade at the surface. As in the case of the rectangular tank, both scum and sludge are usually pumped to the solids or sludge handling facilities.

The clear surface water of the primary tank flows from the tank by passing over a weir. The weir must be long enough to allow the treated water to leave at a low velocity; if it leaves at a high velocity, particles settling to the bottom or those already on the bottom may be picked up and carried from the tank.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 52.

3.5A What is the purpose of flights or plows in a clarifier?

3.5B What happens to the sludge and scum collected in a primary clarifier?

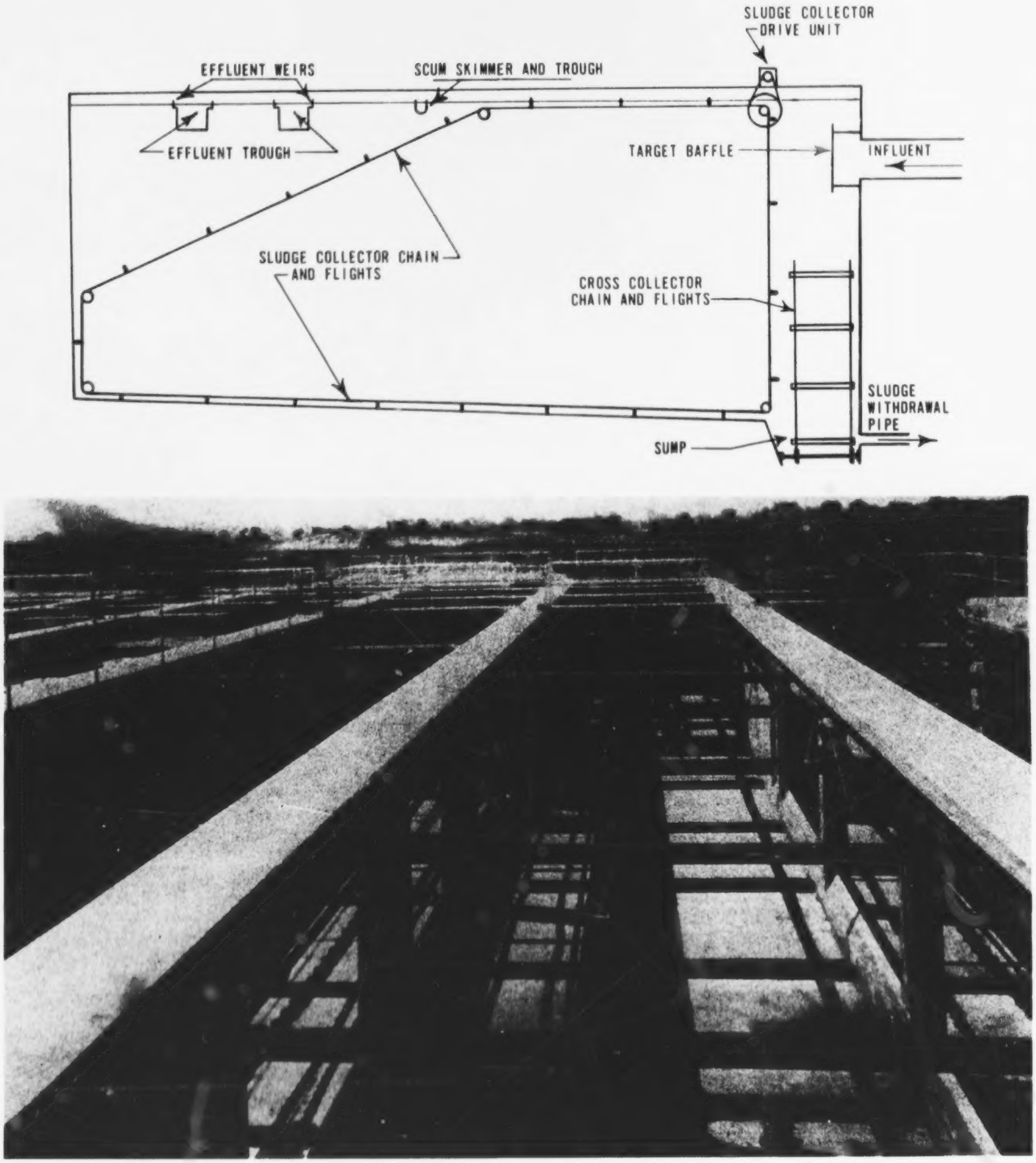
---

[10] *Weir (weer). (1) A wall or plate placed in an open channel and used to measure the flow. The depth of flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.*

[11] *Detention Time. The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to flow through the tank.*

[12] *Biochemical Oxygen Demand (BOD). The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.*

[13] *Sludge (sluj). The settleable solids separated from liquids during processing or the deposits of foreign materials on bottoms of streams or other bodies of water.*


SLUDGE COLLECTOR DRIVE UNIT
EFFLUENT WEIRS
SCUM SKIMMER AND TROUGH
EFFLUENT TROUGH
TARGET BAFFLE
INFLUENT
SLUDGE COLLECTOR CHAIN AND FLIGHTS
CROSS COLLECTOR CHAIN AND FLIGHTS
SLUDGE WITHDRAWAL PIPE
SUMP

(Courtesy Jeffrey)

Fig. 3.14 Rectangular clarifier

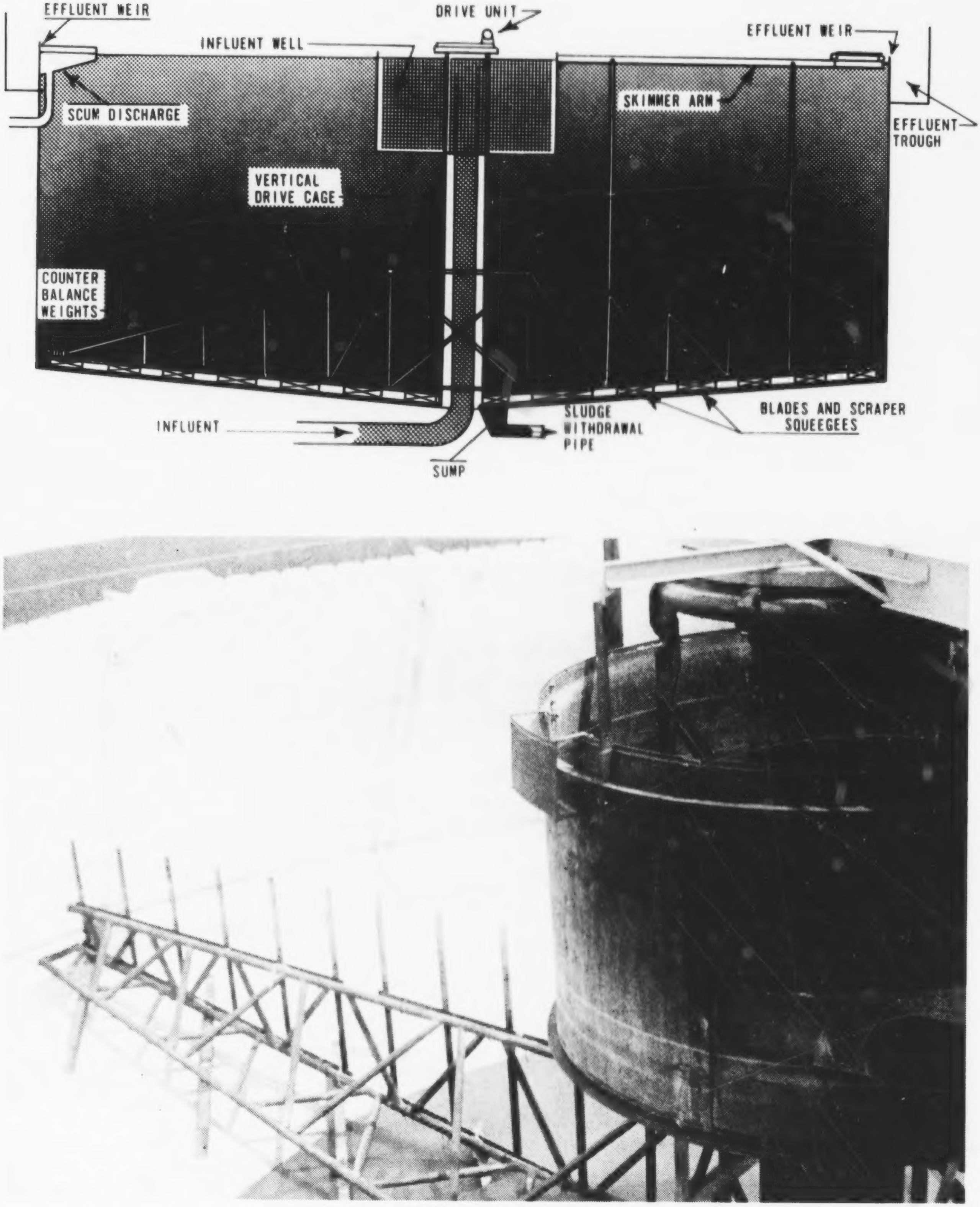

EFFLUENT WEIR
DRIVE UNIT
INFLUENT WELL
EFFLUENT WEIR
SCUM DISCHARGE
SKIMMER ARM
EFFLUENT TROUGH
VERTICAL DRIVE CAGE
COUNTER BALANCE WEIGHTS
INFLUENT
SLUDGE WITHDRAWAL PIPE
BLADES AND SCRAPER SQUEEGEES
SUMP

Fig. 3.15 Circular clarifier

3.6 SECONDARY TREATMENT

3.60 Purpose

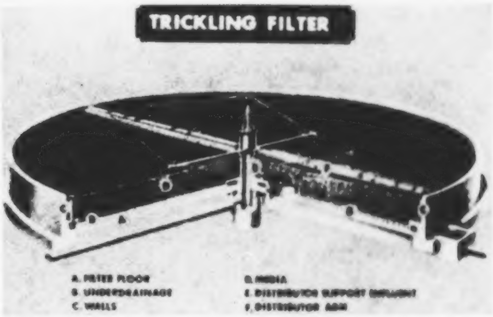
In many treatment plants the wastewater flows from the primary clarifier into another unit where it receives *SECONDARY* or *BIOLOGICAL TREATMENT*. This means that the wastewater is exposed to living organisms (such as bacteria) which eat the dissolved and nonsettleable organic material remaining in the waste. The two processes used almost universally for biological treatment are the *TRICKLING FILTER* and *ACTIVATED SLUDGE*. These are both *AEROBIC* biological treatment processes, which means the organisms require dissolved oxygen (Fig. 3.16) in order to live, eat, and reproduce.

Fig. 3.16 Organisms require dissolved oxygen

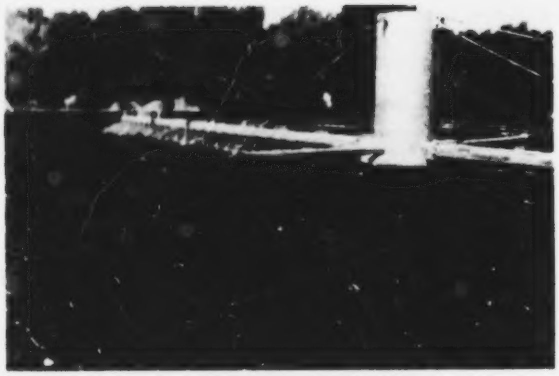
3.61 Trickling Filter (Chapter 6)

The trickling filter is one of the oldest and most dependable of the biological treatment processes. Most of these plants are removing 65 to 85% of the BOD-causing wastes and suspended solids present in the influent.

The trickling filter is a bed of 1½- to 5-inch rock, slag blocks, or specially manufactured *MEDIA*[14] over which settled wastewater from the primary clarifier is distributed (Fig. 3.17). The settled wastewater is usually applied by an overhead rotating distributor and trickles over and around the media as it flows downward to the effluent collection channel. Since the media and the space (voids) in between them are large (usually 2½- to 4-inch [6 to 10 cm] diameter) and since the applied wastewater no longer has any large particles (they settled out in the clarifier), the trickling filter does not remove solids by a filtering action. A more correct term would be to call the filter a "biological contact bed" or "biological reactor" since this is the function it performs. The filter bed offers a place for aerobic bacteria and other organisms to attach themselves and multiply as they feed on the passing wastewater. This process of feeding on, or decomposing waste is exactly the same as the process occurring in the stream when waste is discharged to it. In the trickling filter, however, the organisms use the oxygen which enters the waste from the surrounding air, rather than using up the stream's supply of dissolved oxygen. Thus the voids between the media must be large so sufficient oxygen can be supplied by circulating air.



(Courtesy Water Pollution Control Federation)



(Courtesy Water Pollution Control Federation)

Fig. 3.17 Trickling filter

The wastewater being distributed on the filter usually has passed through a primary clarifier, but it still contains approximately 70 percent of its original organic matter, which represents food for organisms. For this reason a tremendous population of organisms develops on the media. This population continues to grow as more waste is applied. Eventually the layer of organisms on the media gets so thick that some of it breaks off (sloughs off) and is carried into the filter effluent channel. This material is normally called *HUMUS*. Since it is principally organic matter, its presence in a stream would be undesirable. This humus is usually removed by settling in a *SECONDARY CLARIFIER*. Humus sludge from the secondary clarifier is usually returned to the primary clarifier to be resettled and pumped to the sludge handling facilities along with the "raw" sludge which settles out as previously described.

3.62 Rotating Biological Contactors (Chapter 7)

Rotating biological contactors (RBC) are similar to trickling filters and are located after primary clarifiers. Biological contactors have a rotating "shaft" surrounded by plastic discs called the "media." A biological slime grows on the media when conditions are suitable. This process is very similar to a trickling filter where the biological slime grows on rock or other media and settled wastewater (primary clarifier effluent) is applied over the media. With rotating biological contactors, the biological slime grows on the surface of the plastic-disc media. The slime is rotated into the settled wastewater and then into the atmosphere to provide oxygen for the organisms. The wastewater being treated usually flows parallel to the rotating shaft, but may flow perpendicular to the shaft as it flows from stage-to-stage or tank-to-tank. Effluent from the rotating biological contactors flows through secondary clarifiers for removal of suspended solids and dead slime growths.

3.63 Activated Sludge (Chapters 8 and 11)

Another biological treatment unit that is used in secondary treatment, following the primary clarifier, is the aeration tank. When aeration tanks are used with the sedimentation process, the treatment plant is called an *ACTIVATED SLUDGE* plant. The activated sludge process is widely used by large cities and communities where land is expensive and where large volumes must be highly treated, economically, without creating a nuisance to neighbors. The activated sludge plant is probably the most popular biological treatment process being built today for larger installations or small package plants. These plants are capable of BOD and suspended solids reductions of 90 to 99 percent. The activated sludge process is a biological process, and it serves the same function as a trickling filter or rotating biological contactor. Effluent from a primary clarifier is piped to a large aeration tank (Fig. 3.18). Air is supplied to the tank by either introducing compressed air into the bottom of the tank and letting it bubble through the wastewater and up to the top, or by churning the surface mechanically to introduce atmospheric oxygen.

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[14] *Media. The material in a trickling filter on which slime organisms grow. As settled wastewater trickles over the media, slime organisms remove certain types of wastes thereby partially treating the wastewater.*

Aerobic bacteria and other organisms thrive as they travel through the aeration tank. With sufficient food and oxygen they multiply rapidly, as in a trickling filter. By the time the waste reaches the end of the tank (usually 4 to 8 hours), most of the organic matter in the waste has been used by the bacteria for producing new cells. The effluent from the tank, usually called *MIXED LIQUOR*, consists of a suspension containing a large population of organisms and a liquid with very little soluble BOD. The activated sludge forms a lacy network that captures pollutants.

The organisms are removed in the same manner as they were in the trickling filter plant. The mixed liquor is piped to a secondary clarifier, and the organisms settle to the bottom of the tank while the clear effluent flows over the top of the effluent weirs. This effluent is usually clearer than a trickling filter effluent because the suspended material in the mixed liquor settled to the bottom of the clarifier more readily than the material in a trickling filter effluent. The settled organisms are known as *ACTIVATED SLUDGE*. They are extremely valuable to the treatment process. *IF THEY ARE REMOVED QUICKLY FROM THE SECONDARY CLARIFIER, THEY WILL BE IN GOOD CONDITION AND HUNGRY FOR MORE FOOD* (organic wastes) (Fig. 3.19). They are therefore pumped back (recirculated) to the influent end of the aeration tank where they are mixed with the incoming wastewater. Here they begin all over again to feed on the organic material in the waste, decomposing it and creating new organisms.

Left uncontrolled, the number of organisms would eventually be too great, and therefore some must periodically be removed. This is accomplished by pumping a small amount of the activated sludge to the primary clarifier or directly to the sludge handling facilities. If the organisms are pumped to the clarifier, they settle along with the raw sludge and then are removed to the sludge handling facilities.

There are many variations of the conventional activated sludge process, but they all involve the same basic principle. These variations will be discussed in Chapters 8 and 11, "Activated Sludge."

3.64 Secondary Clarifiers (Chapter 5)

As previously mentioned, trickling filters, rotating biological contactors and activated sludge tanks produce effluents that contain large populations of microorganisms and associated materials (humus). These microorganisms must be removed from the flow before it can be discharged to the receiving waters. This task is usually accomplished by a secondary clarifier. In this tank the trickling filter or biological contactor humus or activated sludge separates from the liquid and settles to the bottom of the tank. This sludge is removed to the primary clarifier to be resettled with the primary sludge or returned to the beginning of the secondary process to continue treating the wastewater. In most activated sludge plants the waste activated sludge is pumped to waste sludge handling facilities instead of to the primary clarifier. The clear effluent flows over a weir at the top of the secondary clarifier.

QUESTIONS

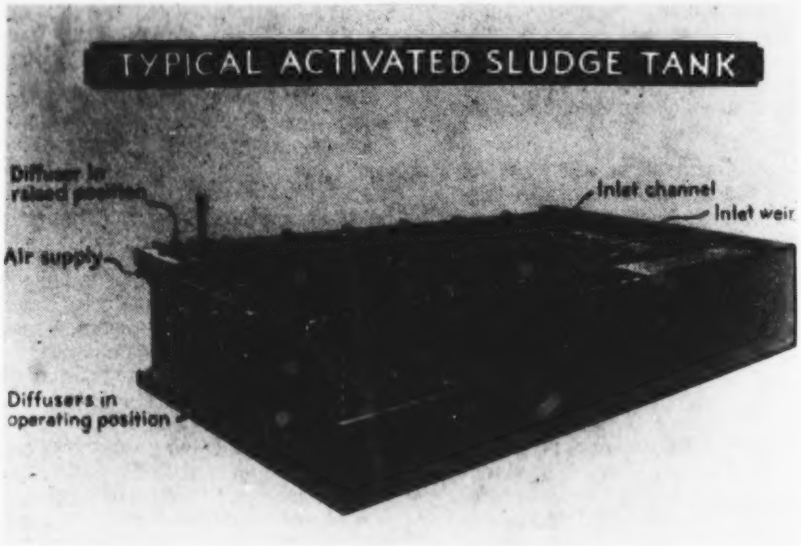
Write your answers in a notebook and then compare your answers with those on page 52.

3.6A Would it be a good idea to use trickling filter media of various sizes so it could pack together better?

3.6B Why is a secondary clarifier needed after a trickling filter, rotating biological contactor, or aeration tank?

3.6C Activated sludge can be pumped from the secondary clarifier to ________________.

Fig. 3.19 Hungry organisms ready for more food


TYPICAL ACTIVATED SLUDGE TANK
Diffuser in raised position
Inlet channel
Inlet weir
Air supply
Diffusers in operating position

(Courtesy Water Pollution Control Federation)

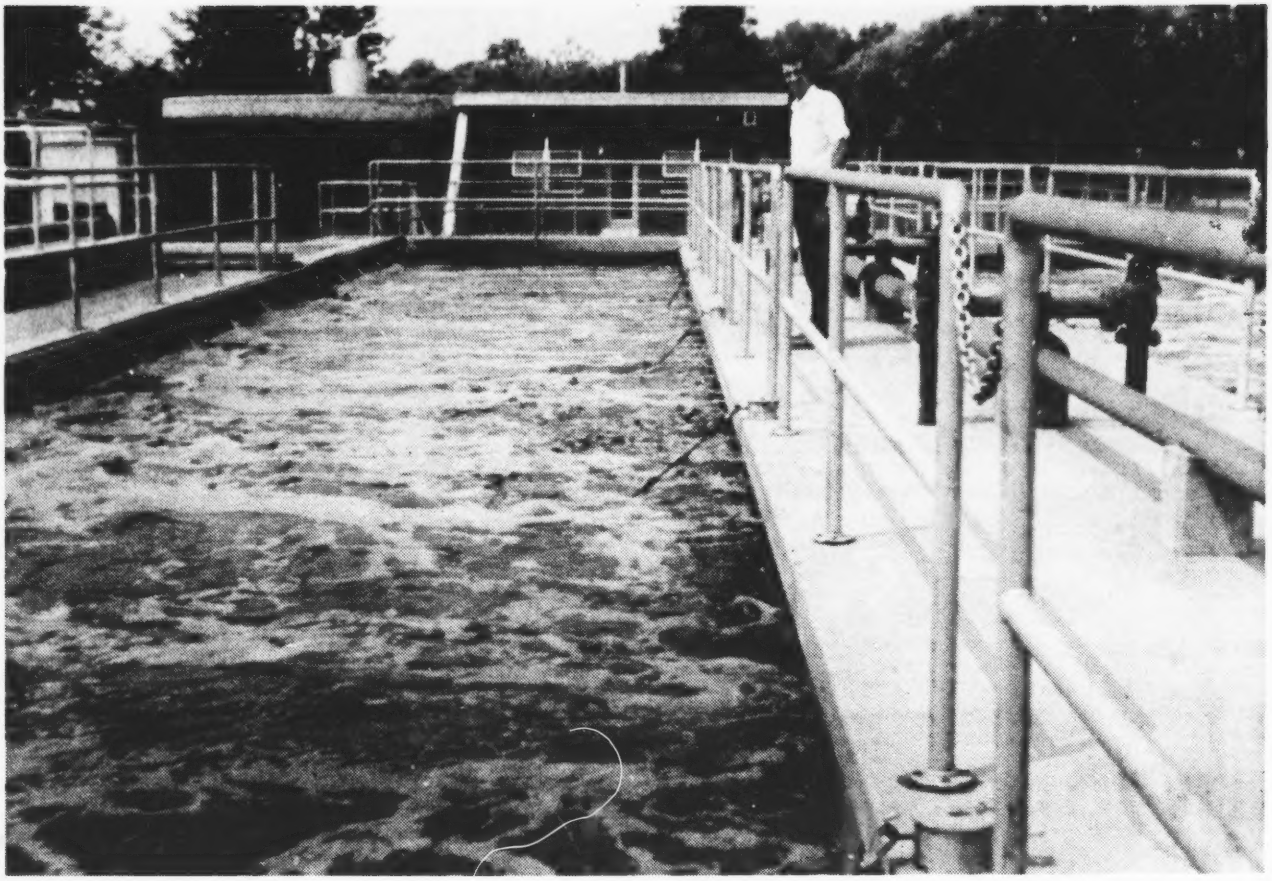


Fig. 3.18 Aeration tank

3.7 SOLIDS HANDLING AND DISPOSAL (Chapter 12)

3.70 Purpose

Solids removed from wastewater treatment processes are commonly broken down by a biological treatment process called *SLUDGE DIGESTION*. After digestion and removal of water (*DEWATERING*),[15] the remaining material may be used as fertilizer or soil conditioner. Some solids such as scum from a clarifier, may be disposed of by burning or burial. Possible solids handling systems are shown on Figures 3.20 and 3.21.

3.71 Digestion and Dewatering

Settled sludge from the primary clarifier and occasionally settled sludge from the secondary clarifier are periodically pumped to a digestion tank. The tank is usually completely sealed to keep air from getting inside (Figures 3.22 and 3.23.) This type of digester is called an *ANAEROBIC DIGESTER* because of the anaerobic bacteria that abound in the tank. Anaerobic bacteria thrive in an environment without dissolved oxygen by using the oxygen which is chemically combined with their food supply.

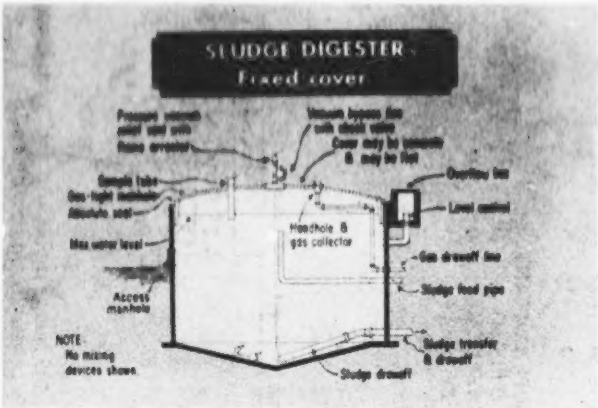


Fig. 3.22 Sludge digester

(Courtesy Water Pollution Control Federation)

Two major types of bacteria are present in the digester. The first group starts eating the organic portion of the sludge to form organic acids and carbon dioxide gas. These bacteria are called *ACID FORMERS*. The second group breaks down the organic acids to simpler compounds and forms methane and carbon dioxide gas. These bacteria are called *GAS FORMERS*. The methane gas is usually used to heat the digester or to run engines in the plant. The production of gas indicates that organic material is being eaten by the bacteria. A sludge is usually considered properly digested when 50 percent of the organic matter has been destroyed and converted to gas. This normally takes approximately 30 days if the temperature is kept at about 95°F (35°C).

Most digestion tanks are mixed continuously to bring the food to the organisms, to provide a uniform temperature, and to avoid the formation of thick scum blankets. When a digester is not being mixed, the solids settle to the bottom, leaving an amber-colored liquid known as *SUPERNATANT* above the sludge. In many plants, digester contents will be the same (no separation of solids and liquids) after two days of sitting without mixing. The supernatant is displaced from the tank each time a fresh charge of raw sludge is pumped from the primary clarifier. The displaced supernatant usually is returned from the digester back to the plant headworks and mixed with incoming raw wastes. Supernatant return should be slow to prevent overloading or shock loading of the plant.

DIGESTER GAS
AIR

Fig. 3.24 Don't allow digester gas and air to mix

A scum blanket will usually develop above the supernatant level. Scum blankets consist of grease, soap, rubber goods, hair, petroleum products, plastics, and filter tips from cigarettes. These scum blankets may contain most of the added food or sludge. Organisms that digest the sludge are usually below the supernatant and little digestion will occur if the organisms and food don't get together. Control of scum blankets consists of mixing the digester contents and burning or burying skimmings instead of pumping them to the digester.

Above the scum blanket or normal water level is the gas collection area. Digester gas is usually around 70 percent methane and about 30 percent carbon dioxide. *WHEN MIXED WITH AIR, DIGESTER GAS IS EXTREMELY EXPLOSIVE* (Fig. 3.24).

In most newer plants digesting takes place in two tanks. The first or primary digester is usually heated and mixed. Rapid digestion takes place along with most of the gas production. In the secondary tank, the digested sludge and supernatant are allowed to separate, thus producing a clearer supernatant and better-digested sludge.

Digester sludge from the bottom of the tank is periodically removed for dewatering. This is accomplished in sand drying beds (Fig. 3.25), lagoons, centrifuges, vacuum filters (Fig. 3.26), and filter presses. The sludge is then burned, buried, or used as fertilizer on certain crops (not on crops which are eaten without cooking). Sludge that has been adequately digested drains readily and is not offensive.

Some of today's activated sludge treatment plants are equipped with aerobic digesters. An aerobic digester is usually an open tank with compressed air being blown through the sludge. Destruction of organic matter is accomplished by bacteria which require dissolved oxygen to survive. The aeration equipment is turned off to allow time for the solids to separate from the water before the supernatant is removed.

One advantage of this process is that no explosive gas is produced. On the other hand, this is also a disadvantage since the anaerobic digester gas is used as a fuel for boilers and engines around the plant. Aerobic sludge from an aerobic digester doesn't thicken as readily as sludge from an anaerobic digester. Aerobic sludge does not filter as well as an equivalent concentration of anaerobic sludge. Supernatant from aerobic digesters is not as strong nor difficult to treat as supernatant from anaerobic digesters.

3.72 Incineration

Sludge may be disposed of by burning if the process does

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[15] *Dewater. To remove or separate a portion of the water present in a sludge or slurry.*

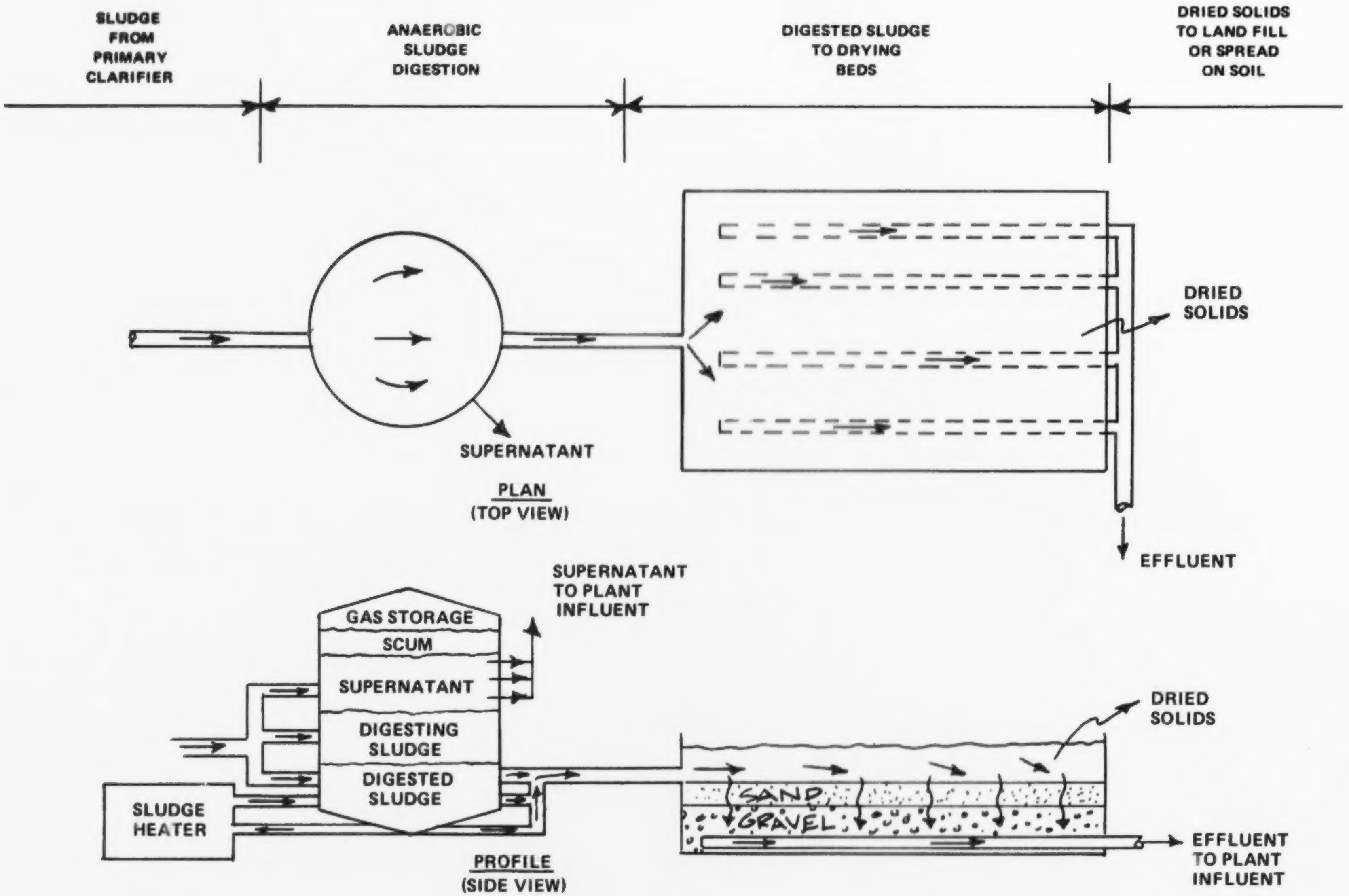

SLUDGE FROM PRIMARY CLARIFIER
ANAEROBIC SLUDGE DIGESTION
DIGESTED SLUDGE TO DRYING BEDS
DRIED SOLIDS TO LAND FILL OR SPREAD ON SOIL
DRIED SOLIDS
SUPERNATANT
PLAN
(TOP VIEW)
EFFLUENT
SUPERNATANT TO PLANT INFLUENT
GAS STORAGE
SCUM
SUPERNATANT
DIGESTING SLUDGE
DIGESTED SLUDGE
SLUDGE HEATER
DRIED SOLIDS
SAND
GRAVEL
EFFLUENT TO PLANT INFLUENT
PROFILE
(SIDE VIEW)

Fig. 3.20 Possible sludge processing and solids disposal flow pattern (sludge drying beds)

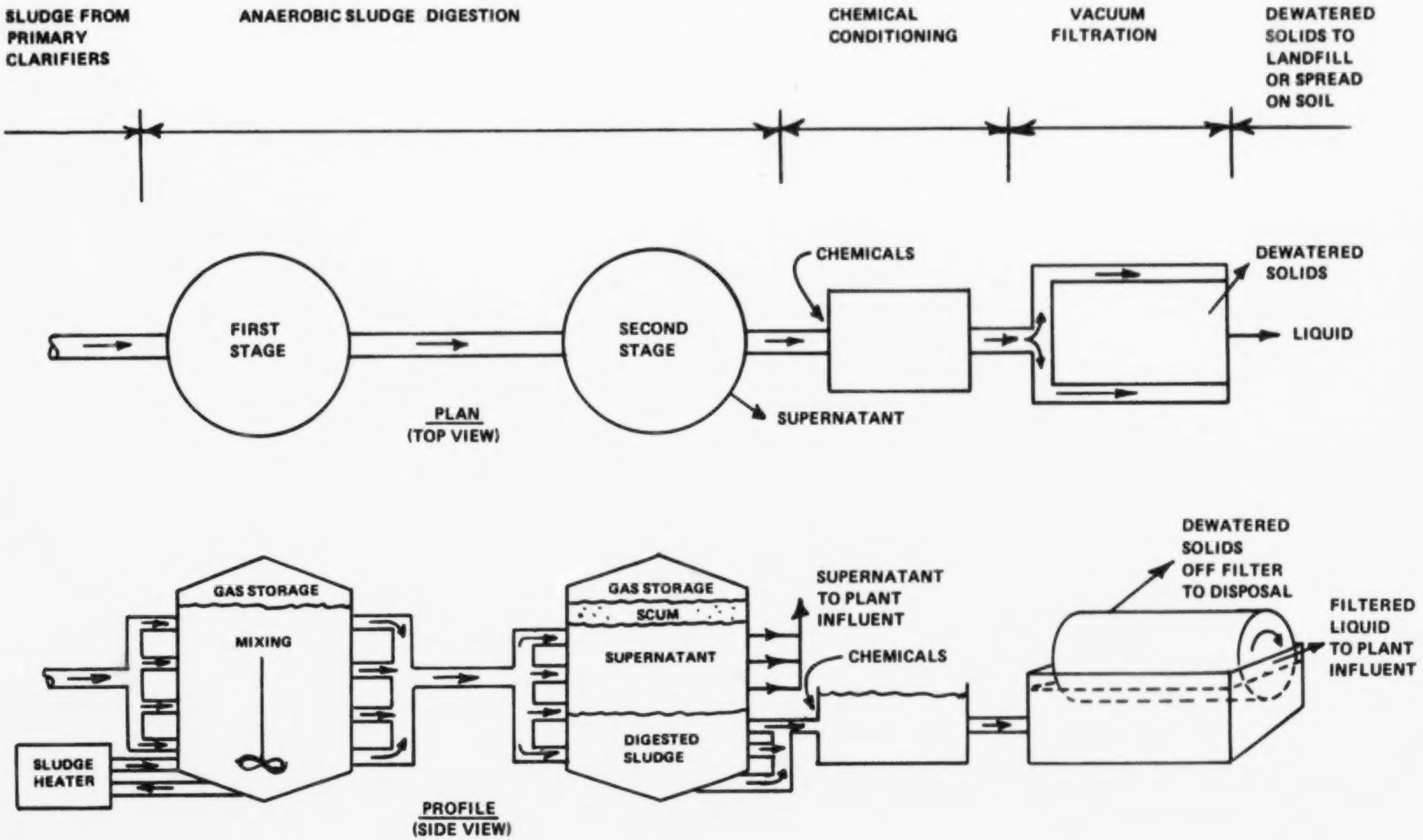

SLUDGE FROM PRIMARY CLARIFIERS
ANAEROBIC SLUDGE DIGESTION
CHEMICAL CONDITIONING
VACUUM FILTRATION
DEWATERED SOLIDS TO LANDFILL OR SPREAD ON SOIL
FIRST STAGE
SECOND STAGE
CHEMICALS
DEWATERED SOLIDS
LIQUID
SUPERNATANT
PLAN
(TOP VIEW)
GAS STORAGE
MIXING
SLUDGE HEATER
GAS STORAGE
SCUM
SUPERNATANT
DIGESTED SLUDGE
SUPERNATANT TO PLANT INFLUENT
CHEMICALS
DEWATERED SOLIDS OFF FILTER TO DISPOSAL
FILTERED LIQUID TO PLANT INFLUENT
PROFILE
(SIDE VIEW)

Fig. 3.21 Possible sludge processing and solids disposal flow pattern (vacuum filtration)

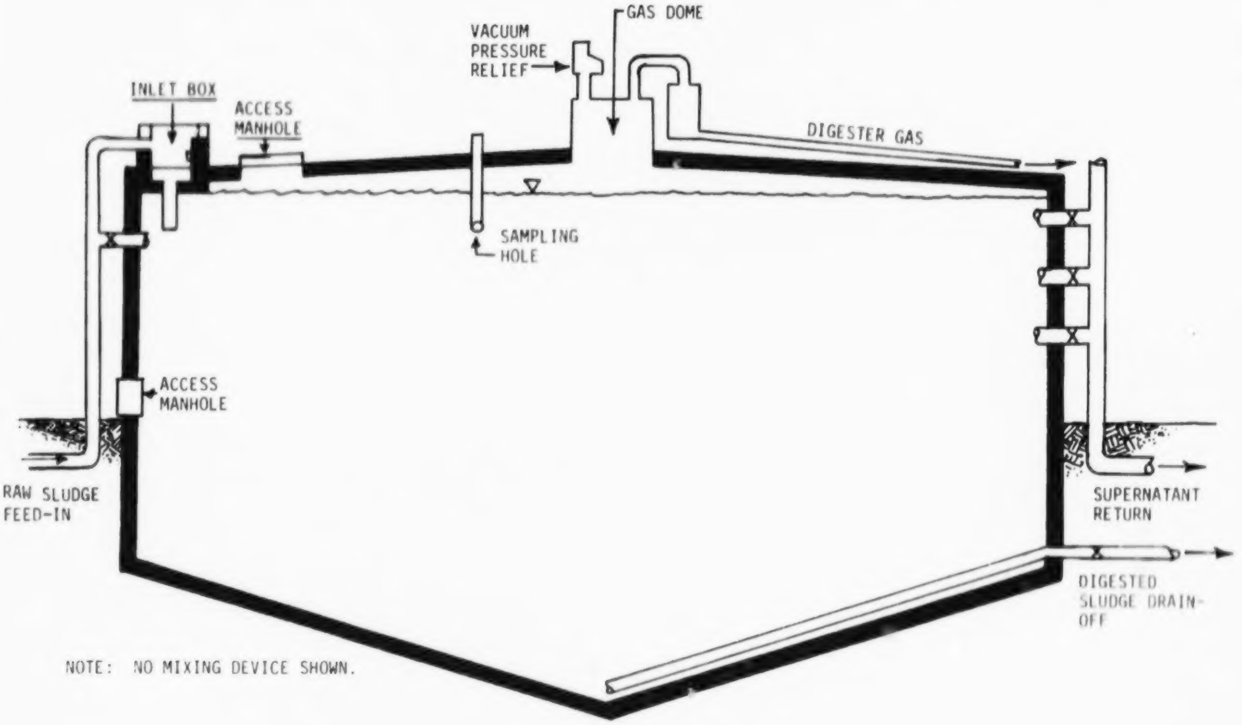
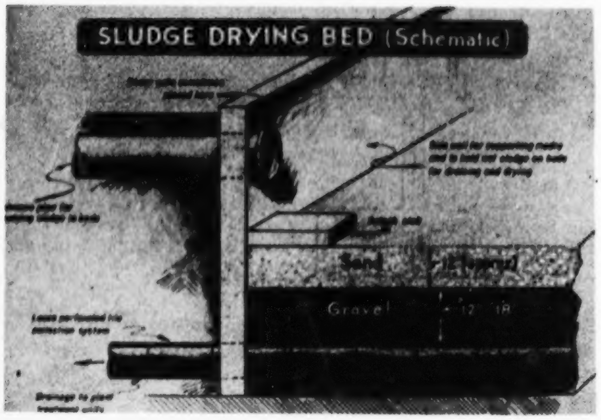
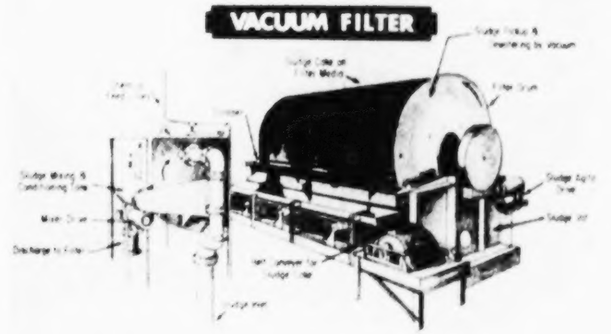

GAS DOME
VACUUM
PRESSURE
RELIEF
INLET BOX
ACCESS
MANHOLE
DIGESTER GAS
SAMPLING
HOLE
ACCESS
MANHOLE
RAW SLUDGE
FEED-IN
SUPERNATANT
RETURN
DIGESTED
SLUDGE DRAIN-
OFF
NOTE: NO MIXING DEVICE SHOWN.

Fig. 3.23 Section of sludge digester


SLUDGE DRYING BED (Schematic)
Sand
Gravel
12" 18"


VACUUM FILTER
Sludge Cake on Filter Media
Filter Drum
Sludge Mixing & Conditioning Tank

(Courtesy Water Pollution Control Federation)

Fig. 3.25 Sludge drying bed

Fig. 3.26 Vacuum filter

not create an air pollution problem. Sludge that has not been dewatered previously can be conditioned by *WET OXIDATION*,[16] dewatered, and then burned. Incineration or burial of skimmings from the clarifiers will prevent treatment plant operational problems.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 52.

3.7A What two basic types of bacteria are present in an anaerobic digester?

3.7B Why are digesters mixed?

3.7C List some of the ways to dewater and dispose of digested sludge.

3.8 WASTE TREATMENT PONDS (Chapter 9)

The waste treatment pond (Fig. 3.27), or stabilization pond, is a special method of biological treatment deserving attention. Ponds do not resemble the concrete and steel structures or the mechanical devices previously discussed, but these simple depressions in the ground are capable of producing an effluent comparable to some of the most modern plants with respect to BOD and bacteria reduction.

The type of treatment processes and the location of ponds are determined by the design engineer on the basis of economics and the degree of treatment required to meet the water quality standards of the receiving waters. In some treatment plants, wastewater being treated may flow through a coarse screen and flow meter before it flows through a series of ponds. Two other types of plants using ponds include locating the ponds after primary treatment and placing them after trickling filters.

When wastewater is discharged to a pond, the settleable solids fall to the bottom just as they do in a primary clarifier. The solids begin to decompose and soon use up all the dissolved oxygen in the nearby water. A population of anaerobic bacteria then continues the decomposition, much the same as in an anaerobic digester. As the organic matter is destroyed, methane and carbon dioxide are released. When the carbon dioxide rises to the surface, some of it is used by algae which convert it to oxygen by the process of *PHOTOSYNTHESIS*.[17] This is the same process used by living plants. Aerobic bacteria, algae, and other microorganisms feed on the dissolved solids in the upper layer of the pond much the same way they do in a trickling filter or aeration tank. Algae produce oxygen for the other organisms to use.

Some shallow ponds (3- to 6-feet deep) have dissolved oxygen throughout their entire depth. These ponds are called aerobic ponds. They usually have a mechanical apparatus adding oxygen as well as their oxygen supply from algae. Another type of aerated pond has oxygen delivered by a diffused air system similar to the system used in activated sludge plants.

Deep (8 to 12 feet), heavily loaded ponds may be without oxygen throughout their depth. These ponds are called anaerobic ponds. At times these ponds can be quite odorous, and they are used only in sparsely populated areas.

Ponds that contain an aerobic top layer and an anaerobic bottom layer are called *FACULTATIVE PONDS*.[18] These are the ponds normally seen in most areas. If they are properly designed and operated, they are virtually odor-free and produce a well-oxidized (low BOD) effluent.

Occasionally ponds are used after a primary treatment unit. In this case, they are usually called "oxidation ponds." When they are used to treat raw wastewater, they are called "raw wastewater lagoons" or "waste stabilization ponds."

The effluent from ponds is usually moderately low in bacteria. This is especially true when the effluent runs from one pond to another or more (series flow). The long detention time, usually a month or more, is required in order for harmful bacteria and undesirable solids to be removed from the pond effluent. If the receiving waters are used for water supply or body contact sports, chlorination of the effluent may still be required.

QUESTION

Write your answers in a notebook and then compare your answers with those on page 52.

3.8A How are facultative ponds similar to the following:
  1. a clarifier?
  2. a digester?
  3. an aeration tank?

3.9 ADVANCED METHODS OF TREATING WASTEWATER (ADVANCED WASTE TREATMENT)

The treatment processes described so far in this chapter are considered *CONVENTIONAL* treatment processes. As our population grows and industry expands, more effective treatment processes will be required. Advanced methods of waste treatment may follow conventional processes, or they may be used instead of these processes. Sometimes advanced methods of waste treatment are called tertiary (TER-she-AIR-ee) treatment because they frequently follow secondary treatment. Advanced methods of waste treatment include coagulation-sedimentation (used in water treatment plants), adsorption, and electrodialysis. Other new treatment processes that may be used in the future include reverse osmosis, chemical oxidation, and the use of polymers.

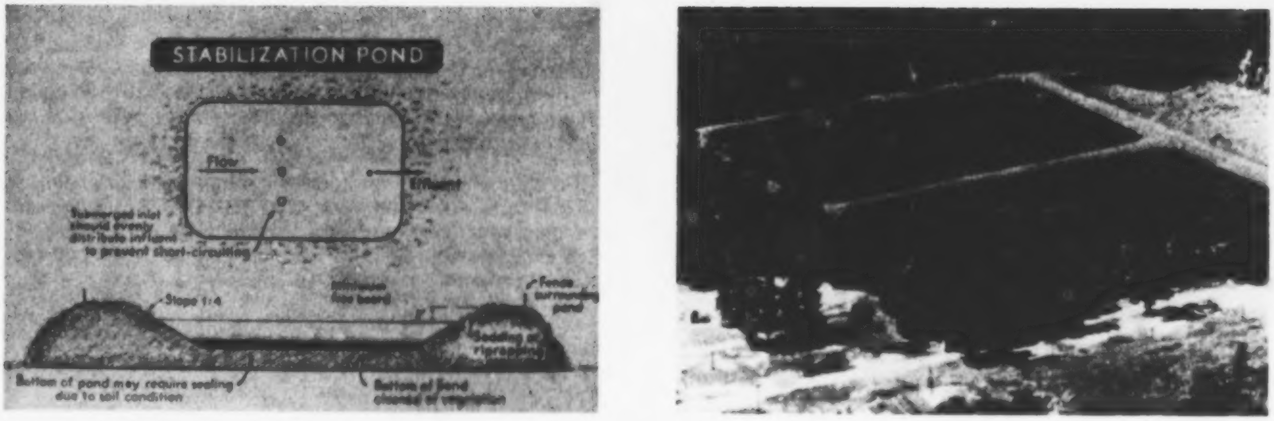
Advanced methods of treatment are used to reduce the nutrient content (nitrate and phosphate) of wastewater to prevent blooms of algae in lakes, reservoirs, or streams. Carbon filters are used to reduce the last traces of organic materials. In some parts of the arid West, advanced methods are used to enable the use of the plant effluent for recreational reservoirs.

---

[16] *Wet Oxidation. A method of treating or conditioning sludge before the water is removed. Compressed air is blown into the liquid sludge. The air and the sludge mixture is fed into a pressure vessel where the organic material is stabilized. The stabilized organic material and inert (inorganic) solids are then separated from the pressure vessel effluent by dewatering in lagoons or by mechanical means.*

[17] *Photosynthesis (foto-SIN-tha-sis). A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. All green plants grow by this process.*

[18] *Facultative Pond (FACK-ul-TAY-tive). The most common type of pond in current use. The upper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.*


STABILIZATION POND
Flow
Effluent
Submerged inlet should evenly distribute influent to prevent short-circuiting
Slope 1:4
Minimum free board
Fence surrounding pond
Sodding or riprapping
Bottom of pond may require sealing due to soil condition
Bottom of pond cleared of vegetation

(Courtesy Water Pollution Control Federation)

(Courtesy Water and Sewage Works Magazine)

Fig. 3.27 Pond

QUESTION

Write your answer in a notebook and then compare your answer with the one on page 52.

3.9A If wastewater from a secondary treatment plant were coagulated with alum or lime and settled in a clarifier, would this be considered a method of advanced waste treatment?

3.10 DISINFECTION (Chapter 10)

Although the settling process and biological processes remove a great number of organisms from the wastewater flow, there remain many thousands of bacteria in every milliliter of wastewater leaving the secondary clarifier. If there are human wastes in the water, it is possible that some of the bacteria are *PATHOGENIC*, or harmful to humans. Therefore, if the treated wastewater is discharged to a receiving water that is used for a drinking water supply or swimming or wading, the water pollution control agency or health department will usually require disinfection of the effluent prior to discharge.

Disinfection is usually defined as the killing of *PATHOGENIC* organisms. The killing of *ALL* organisms is called sterilization. Sterilization is not accomplished in treatment plants as the final effluent always contains some living organisms after disinfection due to the inefficiency of the killing process.

Disinfection can be accomplished by almost any process that will create a harsh environment for the organisms. Strong light, heat, oxidizing chemicals, acids, alkalies, poisons, and many other substances will disinfect. Most disinfection in wastewater treatment plants is accomplished by chlorine, which is a strong oxidizing chemical.

Chlorine gas is used in most treatment plants although some of the smaller plants use a liquid chlorine solution as their source. The dangers in using chlorine gas, however, have prompted some of the larger plants to switch to hypochlorite solution (bleach) even though it is more expensive.

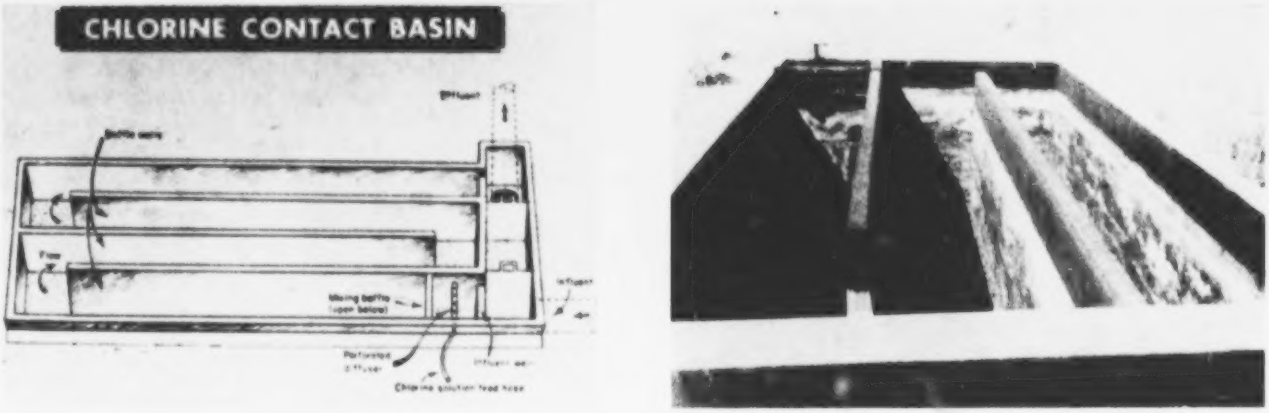
Chlorine gas, which is withdrawn from pressurized cylinders containing liquid chlorine, is mixed with water or treated wastewater to make up a strong chlorine solution. Liquid hypochlorite solution can be used directly. The strong chlorine solution is then mixed with the effluent from the secondary clarifier. Proper and adequate mixing are very important. The effluent is then directed to a chlorine contact basin or tank. The basin can be any size or shape, but better results are obtained if the basin is long and narrow. This shape prevents rapid movement or short-circuiting through the basin. Square or rectangular basins can be baffled to achieve this effect (Fig. 3.28). Basins are usually designed to provide approximately 20 to 30 minutes theoretical contact time, although the trend is to longer times. If the plant's outfall line is of sufficient length, it may function as an excellent contact chamber since short-circuiting will not occur.

In some areas the effluent must be dechlorinated or detoxified before discharge to the receiving waters. Sulfur dioxide (SO_2) has been added after the chlorine contact basin to neutralize the remaining residual chlorine.

3.11 EFFLUENT DISPOSAL (Chapter 13)

Ultimately the effluent from a wastewater treatment plant must be disposed of in the environment. This can be into water, onto land, or the water can be reclaimed and reused. Effluents from most wastewater treatment plants are discharged into receiving waters such as streams, rivers and lakes. With water becoming scarcer due to increased demands and with required higher degrees of treatment, plant effluent is becoming a valuable resource. Both industry and agriculture are discovering that treated effluent may be the most economical source of additional water.

Land disposal is another method of ultimate disposal and can be a means of recharging groundwater basins or storing water for future use. Evaporation ponds are used to dispose of effluents to the atmosphere. Regardless of the method of ultimate effluent disposal, operators must carefully operate wastewater treatment plants so that plant effluent will not cause any adverse impacts on the method of ultimate disposal or on the environment.



(Courtesy Water Pollution Control Federation)

Fig. 3.28 Chlorine contact basin

3.12 SOLIDS DISPOSAL (Chapter 3, ADVANCED WASTE TREATMENT)

Final solids disposal is one of the major problems facing many operators today. Solids removed from wastewater by pretreatment processes such as bar racks, screens and grit removal systems may be disposed of by dewatering and then direct burial in an approved sanitary landfill or incineration with the remaining ash disposed of in a landfill. Grease and scum from primary and secondary treatment processes are usually pumped to anaerobic digesters or disposed of in incinerators or in sanitary landfills.

Both aerobic and anaerobic sludge digestion processes produce stabilized or digested solids that ultimately must be disposed of in the environment. Disposal methods include composting with another material such as leaves, farm land application as a soil conditioner or fertilizer, burial in a sanitary landfill or incineration with ash disposal in a landfill.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 52.

3.10A Does disinfection usually kill all organisms in the plant effluent?

3.10B Which would provide better chlorine contact, a 10,000-gallon cubical tank or a length of 10-inch pipe flowing full and containing the same volume as the cubical tank?

3.13 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read the following sections:

1. A.2 Areas,
2. A.3 Volumes,
3. A.10 Basic Conversion Factors,
4. A.11 Basic Formulas, and
5. A.12 How to Use the Basic Formulas.

Check all of the arithmetic in Sections A.2, Areas (A.20, A.21, A.22, A.23, A.24, A.25 and A.26), and A.3, Volumes (A.30, A.31, A.32, A.33 and A.34), on an electronic pocket calculator. You should be able to get the same answers.

3.14 ADDITIONAL READING

Some books you can read to obtain further information on the treatment plant and the various processes involved are:

1. *MOP 11*;
2. *NEW YORK MANUAL*;
3. *TEXAS MANUAL*; and
4. *BASIC SEWAGE TREATMENT OPERATION*, Publications Centre, Ontrario Ministry of Government Services, 880 Bay Street, 5th Floor, Toronto, Ontario, CANADA M7A 1N8. Price $6.50 in Canadian funds only.

SUGGESTED ANSWERS

Chapter 3. WASTEWATER TREATMENT FACILITIES

Answers to questions on page 30.

3.1A The operator should know the origin of wastes reaching the plant, the time it takes, and how the wastes are transported (flow by gravity or by gravity and pumped). Such knowledge will help you to spot troubles and take corrective action.

3.1B Sanitary, storm, combined.

3.1C If the flow time to reach the plant is very long, hydrogen sulfide gas may develop and cause corrosion damage to concrete in the transportation system and in the plant. Also undesirable odors develop and solids are difficult to settle.

3.1D Flows are sometimes bypassed during storms because a plant does not have the capacity to handle the additional storm water runoff.

Answers to questions on page 38.

3.3A Grit should be removed early in the treatment process because it is abrasive and will wear out pumps and other equipment.

3.3B Grit removed from the wastewater is usually buried to avoid causing a nuisance.

Answers to questions on page 39.

3.4A Weirs are not frequently used to measure influent flows because solids may collect behind the weir causing odors and inaccurate flow measurements.

3.4B Parshall Flumes are widely used for measuring wastewater flow because they have no obstructions.

Answers to questions on page 39.

3.5A "Flights" in rectangular tanks move scum along the surface to a scum trough and push sludge along the bottom to a hopper for removal to the sludge handling facility. "Plows" scrape sludge along the bottom of circular tanks to a hopper for removal.

3.5B Sludge and scum are usually pumped to sludge handling facilities such as digesters. Scum should be burned or buried if possible.

Answers to questions on page 43.

3.6A No. If the media were packed together, air could not circulate and the organisms on the media would not get enough oxygen.

3.6B A secondary clarifier is needed after a trickling filter, rotating biological contactor or aeration tank to allow organisms in treated wastewater to be removed by settling.

3.6C Aeration tank or waste sludge handing facilities. Activated sludge could be pumped to either of the two places listed.

Answers to questions on page 49.

3.7A (1) a group that eats organic sludge to form organic acids and carbon dioxide gas (acid formers); and (2) a group that breaks down the organic acids into simpler compounds and forms methane and carbon dioxide gas (gas formers).

3.7B Digesters are mixed to bring food and organisms together and prevent the formation of a scum blanket.

3.7C Digested sludge may be dewatered by using sand drying beds, centrifuges, vacuum filters, or lagoons. Ultimately the dried sludge may be used as a soil conditioner or it may be buried.

Answer to question on page 49.

3.8A A facultative pond acts like a clarifier by allowing solids to settle to its bottom, like a digester because solids on the bottom are decomposed by anaerobic bacteria, and like an aeration tank because of the action of aerobic bacteria in the upper layer of the pond.

Answer to question on page 50.

3.9A Yes.

Answers to questions on page 51.

3.10A No.

3.10B The pipe would provide better chlorine contact because water cannot short-circuit (take a short route) through a pipe, while it might not move evenly through a tank and thus some of the water would have a shorter contact time.

OBJECTIVE TEST

Chapter 3. WASTEWATER TREATMENT FACILITIES

Please mark correct answers in the proper columns on the answer sheet, as directed at the end of Chapter 1. Return your answer sheet to your Project Director.

1. Name three different types of sewers.
   1. Conventional, surface, combined
   2. Sanitary, pipes, storm
   3. Sanitary, storm, combined
   4. Sanitary, storm, conventional
   5. Sanitary, storm, groundwater
2. Combined sewers (1. *ARE*) or (2. *ARE NOT*) a problem to treatment plant operators.
3. Which of the following are biological treatment processes?
   1. Digesters
   2. Grit removal
   3. Ponds
   4. Shredders
   5. Trickling filters
4. The purpose of screening is to
   1. Grade the solids into different sizes.
   2. Prevent large solids from plugging pumps and pipes.
   3. Protect public health.
   4. Remove large objects and debris.
   5. Thin the wastewater.
5. Flow measurements are important because they are used to
   1. Adjust pumping rates.
   2. Determine chlorination rates.
   3. Determine if a plant is handling its design capacity.
   4. Determine loading on treatment units.
   5. Determine treatment efficiency.
6. The solids settled in a clarifier are called
   1. Colloidal solids.
   2. Dissolved solids.
   3. Emulsions.
   4. Scum.
   5. Sludge.
7. The trickling filter (1. *DOES*) or (2. *DOES NOT*) remove solids by a filtering action.
8. Why is the mixture of digester gas and air dangerous?
   1. It kills grass.
   2. It may explode.
   3. It stinks.
9. (1. Disinfection) or (2. Sterilization) is usually defined as the killing of pathogenic organisms, and
10. The killing of all organisms is called (1. Disinfection) or (2. Sterilization).
11. Ponds are capable of reducing
    1. BOD and bacteria.
    2. Land area and cost.
    3. Mosquitoes and weeds.
    4. Odors and algae.
    5. None of these.
12. Effluent from a wastewater treatment plant may be disposed of by
    1. Discharging into receiving waters.
    2. Discharging onto land.
    3. Evaporating into the atmosphere.
    4. Recharging ground water.
    5. Reclaiming and reusing.

END OF OBJECTIVE TEST

CHAPTER 4

RACKS, SCREENS, COMMINUTORS AND GRIT REMOVAL

(PRETREATMENT)

by

Larry Bristow

TABLE OF CONTENTS

Chapter 4. Racks, Screens, Comminutors and Grit Removal

Page

OBJECTIVES 57

GLOSSARY 58

4.0 Caution 61

4.1 Pretreatment 61

4.2 Bar Screens and Racks 62

  4.20 Safety Around Bar Screens and Racks 64

  4.21 Manually Cleaned Bar Screens 64

  4.22 Mechanically Cleaned Screens 67

  4.23 Operational Procedures 68

4.3 Disposal of Screenings 68

4.4 Comminution 69

  4.40 Comminutors 69

  4.41 Barminutors 76

  4.42 Operational Procedures 76

4.5 Grit Removal 80

4.6 Grit Channels 80

4.7 Cyclone Grit Separators 86

  4.70 Safety 89

  4.71 Start Up 89

  4.72 Operation 89

  4.73 Shutdown 89

  4.74 Maintenance 89

4.8 Grit Washing 90

4.9 Quantities of Grit 90

4.10 Disposal of Grit 92

4.11 Pre-aeration 92

4.12 Operational Strategy 92

4.13 Design Review 93

  4.130 Racks and Screens 93

  4.131 Grit Removal 93

  4.132 Wet Wells 93

4.14 Arithmetic Assignment 93

4.15 Additional Reading 93

4.16 Metric Calculations 93

  4.160 Conversion Factors 94

  4.161 Problem Solutions 94

OBJECTIVES

Chapter 4. RACKS, SCREENS, COMMINUTORS AND GRIT REMOVAL

At the beginning of the remaining chapters you will find a list of *OBJECTIVES*. The purpose of this list is to stress the most important topics in the chapter. Contained in the list will be items you need to know and skills you must develop to operate and to maintain your plant as efficiently and safely as possible.

Following completion of Chapter 4, you should be able to do the following:

1. Explain the purposes of racks, screens, comminutors, grit channels, grit separators, and pre-aeration,
2. Properly start up, operate, shut down, and maintain the pretreatment process,
3. Identify potential safety hazards and conduct pretreatment duties using safe procedures,
4. Determine the volume of screenings and how long a disposal site will last before it is full,
5. Measure the flow velocity in a grit channel,
6. Regulate flow velocities in a grit channel,
7. Develop an operational strategy for pretreatment processes, and
8. Review plans and specifications for pretreatment processes.

NOTE: Information on maintenance of equipment is in Chapter 15, "Maintenance."

GLOSSARY

AEROBIC DECOMPOSITION (AIR-O-bick) AEROBIC DECOMPOSITION

The decay or breaking down of organic material in the presence of "free" or dissolved oxygen.

ALKALINITY (AL-ka-lin-ity) ALKALINITY

The capacity of water or wastewater to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.

ANAEROBIC DECOMPOSITION (AN-air-O-bick) ANAEROBIC DECOMPOSITION

The decay or breaking down of organic material in an environment containing no "free" or dissolved oxygen.

BUFFER BUFFER

A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BUFFER CAPACITY BUFFER CAPACITY

A measure of the capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water or wastewater for offering a resistance to changes in pH.

CLARIFIER (KLAIR-i-fire) CLARIFIER

Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time, during which the heavier solids settle to the bottom and the lighter material will float to the water surface.

DECOMPOSITION, DECAY DECOMPOSITION, DECAY

Processes that convert unstable materials into more stable forms by chemical or biological action. Waste treatment encourages decay in a controlled situation so the material may be disposed of in a stable form. When organic matter decays under anaerobic conditions (putrefaction), undesirable odors are produced. The aerobic processes in common use for wastewater treatment produce much less objectionable odors.

DETRITUS (dee-TRI-tus) DETRITUS

The heavy, coarse mixture of grit and organic material carried by wastewater.

DIFFUSER DIFFUSER

A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DIGESTER (die-JEST-er) DIGESTER

A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic (more common) or aerobic conditions.

DISSOLVED OXYGEN DISSOLVED OXYGEN

Molecular oxygen dissolved in water or wastewater, usually abbreviated DO.

EFFLUENT (EF-lu-ent) EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

EXPLOSIMETER EXPLOSIMETER

An instrument used to detect explosive atmospheres. When the **L**ower **E**xplosive **L**imit (L.E.L.) of an atmosphere is exceeded, an alarm signal on the instrument is activated.

GRIT GRIT

The heavy mineral material present in wastewater, such as sand, gravel, cinders, and eggshells.

GRIT REMOVAL GRIT REMOVAL

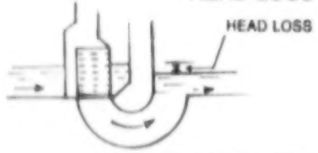
Grit removal is accomplished by providing an enlarged channel or chamber which causes the flow velocity to be reduced and allows the heavier grit to settle to the bottom of the channel or chamber where it can be removed.

HEAD HEAD

A term used to describe the height or energy of water above a point. A head of water may be measured in either height (feet or meters) or pressure (pounds per square inch or kilograms per square centimeter).

HEAD LOSS HEAD LOSS

An indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, comminutor, filter or other obstruction. The amount of energy or pressure lost is called "head loss." Head loss is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters.



HYDROGEN SULFIDE (H_2S) HYDROGEN SULFIDE

Hydrogen sulfide is a gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls your sense of smell so that you don't notice it after you have been around it for a while and because the odor is not noticeable in high concentrations. The gas is very poisonous to your respiratory system, explosive, flammable and colorless.

INFLUENT (IN-flu-ent) INFLUENT

Wastewater or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process, or treatment plant.

INORGANIC MATERIAL INORGANIC MATERIAL

Material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Inorganic materials are chemical substances of mineral origin; whereas organic materials are chemical substances usually of animal or plant origin.

LIMIT SWITCH LIMIT SWITCH

A device that regulates or controls the travel distance of a chain or cable.

O & M MANUAL O & M MANUAL
(**O**peration and **M**aintenance Manual)

A manual which outlines procedures for operators to follow to operate and maintain a specific wastewater treatment plant and the equipment in the plant.

ORGANIC MATERIAL ORGANIC MATERIAL

Material which comes mainly from animal or plant sources. Organic material generally can be consumed by bacteria and other small organisms. Inorganic materials are chemical substances of mineral origin.

OZONIZATION (O-zoe-nie-ZAY-shun) OZONIZATION

The application of ozone to water, wastewater, or air, generally for the purposes of disinfection or odor control.

PRE-AERATION PRE-AERATION

The addition of air at the initial stages of treatment to freshen the wastewater, remove gases, add oxygen, promote flotation of grease, and aid coagulation.

PRETREATMENT PRETREATMENT

The removal of metal, rocks, rags, sand, eggshells, and similar materials which may hinder the operation of a treatment plant. Pretreatment is accomplished by using equipment such as racks, bar screens, comminutors, and grit removal systems.

PUTREFACTION (PEW-tree-FACK-shun) PUTREFACTION

Biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions.

PUTRESCIBLE (pew-TRES-uh-bull) PUTRESCIBLE

Material that will decompose under anaerobic conditions and produce nuisance odors.

RACK RACK

Evenly spaced parallel metal bars or rods located in the influent channel to remove rags, rocks and cans from wastewater.

RAW WASTEWATER RAW WASTEWATER

Plant influent or wastewater before treatment.

SCREEN SCREEN

A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SHEAR PIN SHEAR PIN

A straight pin with a groove around the middle that will weaken the pin and cause it to fail when a certain load or stress is exceeded. The purpose of the pin is to protect equipment from damage due to excessive loads or stresses.

SLUDGE (sluj) SLUDGE

The settleable solids separated from liquids during processing, or the deposits of foreign materials on the bottoms of streams or other bodies of water.

SLUDGE DIGESTION SLUDGE DIGESTION

The process of changing organic matter in sludge into a gas or a liquid or a more stable solid form. These changes take place as microorganisms feed on sludge in anaerobic (more common) or aerobic digesters.

SLURRY (SLUR-e) SLURRY

A thin watery mud, or any substance resembling it (such as a grit slurry or a lime slurry).

SPECIFIC GRAVITY SPECIFIC GRAVITY

Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles usually have a specific gravity of 0.5 to 2.5

WEIR, PROPORTIONAL (weer) WEIR, PROPORTIONAL

A specially shaped weir in which the flow through the weir is directly proportional to the head.

CHAPTER 4. RACKS, SCREENS, COMMINUTORS AND GRIT REMOVAL

4.0 CAUTION

Many wastewater treatment plant operators have been seriously injured due to avoidable accidents. According to regular surveys by the Water Pollution Control Federation, the wastewater treatment and pollution control industry has a higher accident rate than most industries reporting to the National Safety Council. Working in a wastewater treatment plant is not necessarily more dangerous than working in other industries. The poor record of the past may have been caused by operators not being aware of unsafe conditions, not immediately correcting these conditions when they became obvious, and not knowing safe procedures.

There are many potential safety hazards around a wastewater treatment plant. *ACCIDENTS CAN BE REDUCED BY THINKING SAFETY*. You should protect yourself from injury by maintaining firm footing, keeping walk areas clear, immediately cleaning up spills, and shutting off, tagging and locking out the electrical power before working on equipment.

You must take adequate precautions to prevent becoming infected with water-borne diseases such as dysentery or typhoid. At any given moment, some people in your community are ill; disease bacteria and viruses from these people are in the wastewater reaching your plant. When cleaning equipment such as pumps, bar screens and grit channels, you often must place your hands in raw wastewater. Also, the tools used to work on equipment frequently become contaminated. Consequently, *GOOD PERSONAL HYGIENE MUST BE OBSERVED BY ALL OPERATORS AT ALL TIMES. ALWAYS WASH YOUR HANDS THOROUGHLY BEFORE EATING OR SMOKING*.

A good practice is to change work clothing before going home. Any clothing that has been worn at the wastewater treatment plant must be laundered separately from the family wash.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

TRUE OR FALSE:

4.0A The wastewater and pollution control industry has a higher accident rate than most other industries reporting to the National Safety Council.

4.0B Electrical power must always be shut off before working on equipment.

4.0C Operators must wash their hands thoroughly before eating, smoking or going home.

4.1 PRETREATMENT

In various ways, a little or a lot of almost everything finds its way into sewers and ends up at the wastewater treatment plant. Cans, bottles, pieces of scrap metal, sticks, rocks, bricks, plastic toys, plastic lids, caps from toothpaste tubes, towels and other rags, sand — all are found in the plant *INFLUENT*.[1]

These materials are troublesome in various ways. Pieces of metal, rocks, and similar items will cause pipes to plug, may damage or plug pumps, or jam sludge collector mechanisms in settling tanks (*CLARIFIERS*).[2] Sand, eggshells, and similar materials (grit) can plug pipes, cause excessive wear in pumps, and use up valuable space in the sludge *DIGESTERS*.[3]

If a buried or otherwise inaccessible pipe is plugged, or a sludge collector mechanism jams, or a critical pump is put out of commission, serious consequences can result. A plant operating at reduced efficiency increases the pollution level of the effluent discharged into receiving waters. This can cause health hazards to downstream water users, sludge deposits in a stream or lake (with resultant odors and unsightliness), and sometimes the death of fish and other aquatic life. Also, repairs of this type involve a good deal of hard (sometimes rather unpleasant) work and usually result in large, unbudgeted expenses.

---

[1] *Influent (IN-flu-ent). Wastewater or other liquid – raw or partly treated – flowing* INTO *a reservoir, basin, treatment process, or treatment plant.*

[2] *Clarifier (KLAIR-i-fire) (settling tank, sedimentation basin). A tank or basin in which wastewater is held for a period of time, during which the heavier solids settle to the bottom and the lighter material will float to the water surface.*

[3] *Digester (die-JEST-er). A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic (more common) or aerobic conditions.*

With these things in mind, it is evident that an important part of a wastewater treatment plant is the equipment used to remove rocks, large debris, grit and other materials as early as possible. These items of equipment include screens, racks, comminutors, and grit removal devices and are called "pretreatment facilities."

SCREENING is that part of the pretreatment facilities which removes the larger debris (rocks, cans, bottles, rags). This equipment may consist of parallel bars or slotted drums through which the wastewater must pass. Accumulated debris is removed from the screens either manually or mechanically. In some plants, cutters shred the rags and debris accumulated on the screens or drums, return the shredded materials to the flow, and allow them to pass through the screens to continue in the wastewater flow. This is considered a poor practice because this material could interfere with downstream treatment processes.

GRIT REMOVAL involves removing the heavy *INORGANIC MATERIAL*,[4] such as sand and gravel, from the wastewater. This is done by reducing the velocity of the wastewater enough so that the heavier particles settle to the bottom of special channels or hoppers. The grit may be further processed (separated or dewatered) in cyclone separators or grit classifiers (washers). Grit usually flows from the hoppers, to the cyclone separator, and then to the classifier. Final disposal of the grit is usually by burial which can be rather unpleasant and costly work.

PRE-AERATION is used to freshen the wastewater and separate oils and grease. This process tends to increase the overall efficiency of solids and BOD removal.

See Fig. 4.1 for the location of these processes in a typical plant. Your plant may differ in some respects from the arrangement shown because of differences in one or more of the following factors: quantity of wastewater; characteristics of the wastewater; seasonal variations in quantity and characteristics; discharge requirements; construction, operating, and maintenance costs of various processes; and the designer's preferences.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

4.1A The following items may be found in a treatment plant influent:

- a. Cans
- b. Toys
- c. Rubber Goods
- d. Pieces of Wood
- e. All of These

4.1B What items of equipment are used to remove rocks, pieces of wood, metal, and rags from wastewater?

4.1C Why should coarse debris (rocks, boards, metal) be removed at the plant entrance or headworks?

4.2 BAR SCREENS AND RACKS

Parallel bars may be placed at an angle or vertical in a channel in such a manner that the wastewater will flow through the bars, but large solids and debris will be caught on the bars. These bars are commonly called "racks" when the spacing between them is 3 to 4 inches (7.6 to 10.2 cm) or more. When the spacing is about ⅜ inch to 2 inches (0.95 to 5.1 cm), they are called "bar screens." Bar screens are used to screen the influent flow on a continuous basis and are usually mechanically cleaned. Usually racks are found in bypass channels where flows are diverted when bar screens are being serviced or repaired. Bar racks are manually cleaned due to their infrequent use.

Various other mechanical screening methods are in use involving actual coarse screens or perforated sheet metal. These units are automatically cleaned with scrapers, rotating brushes, water sprays, or air jets. The screens may be in the form of belts, discs, or drums set in a channel so that the wastewater flows through the submerged portion. The collected debris is removed as it passes the brushes or sprays.

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[4] *Inorganic Material. Material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Inorganic materials are chemical substances of mineral origin; whereas organic materials are chemical substances usually of animal or plant origin.*

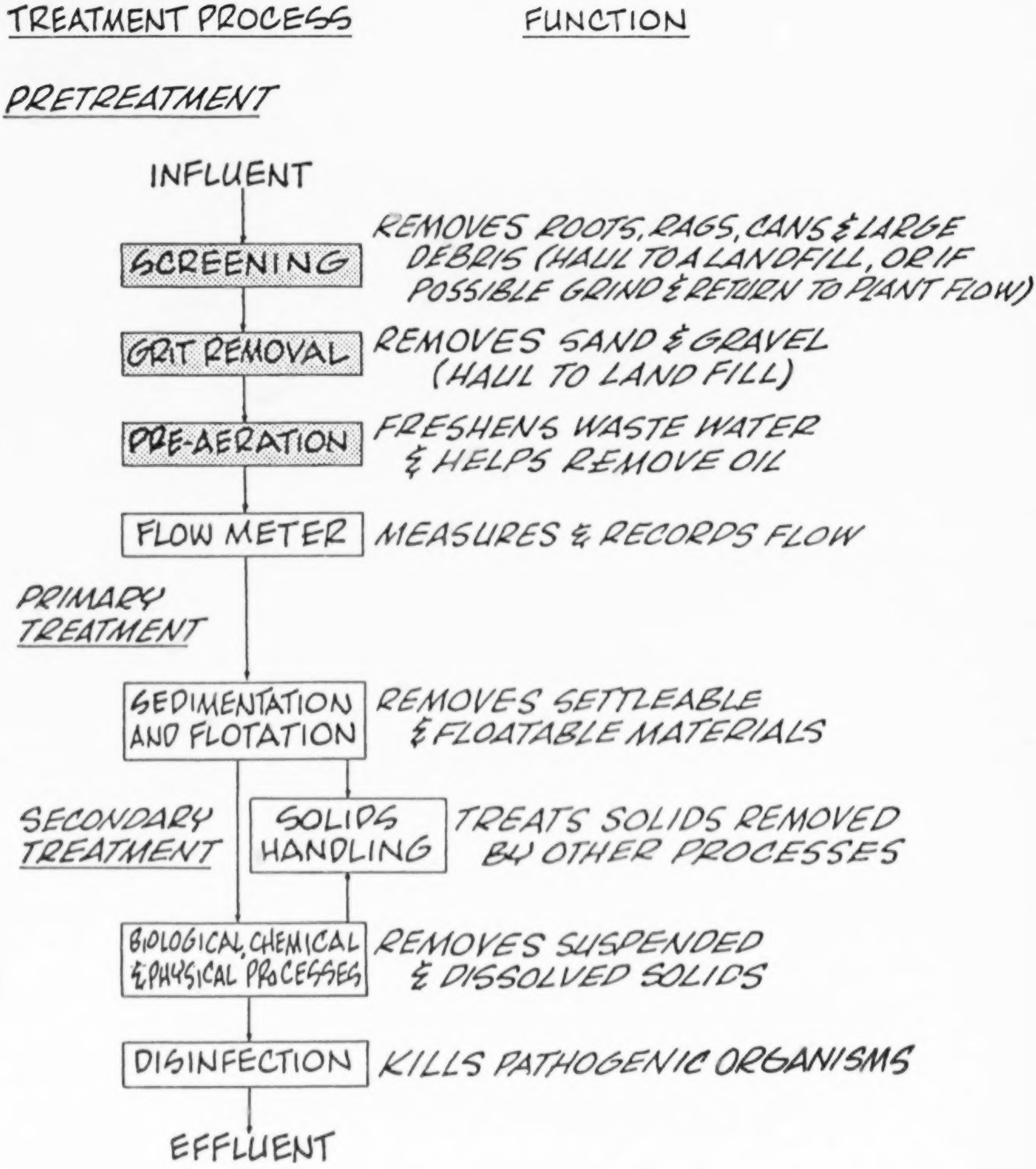
TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
BIOLOGICAL, CHEMICAL & PHYSICAL PROCESSES
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
EFFLUENT

Fig. 4.1 Flow diagram of typical plant

These devices usually are not used in pretreatment, but are installed at the outlets of clarifiers or chlorine contact basins and at industrial pretreatment facilities. To maintain screening equipment, look for specific information in the manufacturer's literature, the plant *O & M MANUAL*,[5] or in Chapter 15, "Maintenance."

4.20 Safety Around Bar Screens and Racks

Whenever you work around open channels or tanks, be careful not to trip or slip and fall into the wastewater or moving machinery. Falling into wastewater exposes you to disease, to the possibility of drowning, and obviously to a very unpleasant bath. Stay behind guardrails whenever possible. When working on mechanical equipment, tag operating controls and lock power off, and keep the key with *YOU*. Run mechanical equipment only when the guards are in place over moving parts. The area should be posted "No Smoking" because of the possibility of explosive materials and gases from industrial discharges in the plant influent.

Before starting to rake material from a manually cleaned bar screen, examine the area for objects or structures which might interfere with the rake handle and knock you off balance. Determine if there are any guardrails, corners of buildings or diversion structures, light posts or overhead lights, or electrical wires which the end of the rake might hit. Do not stand on a slippery surface while raking material.

Back injuries, hernias, and muscle strains can occur from pulling too hard when lifting inlet or outlet gates or pulling heavy, water-logged debris from the racks. Never attempt to lift gates or rake debris that requires more strength than you can exert safely. When lifting heavy objects, always keep your back straight, bend at your knees, and lift with your leg muscles.

4.21 Manually Cleaned Bar Screens

A manually cleaned bar screen is shown on Figures 4.2 and 4.3, and the purposes of the parts are summarized in Table 4.1. These bar screens require frequent attention. As debris collects on the bars, it blocks the channel and causes wastewater to back up into the sewer. The more debris that collects on the bars, the greater the *HEAD LOSS*[6] through the bar screens. As the flow backs up, *ORGANIC MATERIALS*[7] tend to settle out in the channel and sewer, depleting the *DISSOLVED OXYGEN*[8] in the wastewater. Subsequently, *SEPTIC*[9] conditions develop.

The septic conditions produce *HYDROGEN SULFIDE*[10] which has a rotten-egg odor; causes corrosion to concrete, metal, and paint; and also sometimes produces a toxic and explosive atmosphere in a poorly ventilated room. If cleaning of the bar screens is infrequent, wastewater can back up and overflow the influent channel or flow through the bypass channel and bar rack. In either case, larger debris will be allowed to enter downstream treatment units. When the bar screens are cleaned, a sudden rush of septic wastewater can create a "shock load" on the treatment processes. The sudden high flow may carry grit into the clarifiers or carry additional solids over the clarifier weirs, reducing the efficiency of the clarifiers and secondary treatment units. Also increased odors will most likely result. Thus, failure to keep the bar screens clean will result in the lowering of the quality of the *EFFLUENT*[11] whenever a shock load of septic wastewater is released.

Cleaning of manually cleaned bar screens may be accomplished with a rake with tines (prongs) which will fit between the bars. The debris is raked to the top of the rack or into the drainage trough (whichever is provided). After draining, the debris is placed into the container provided (a bin or garbage can).

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[5] *O & M Manual (Operation and Maintenance Manual). A manual which outlines procedures for operators to follow to operate and maintain a specific wastewater treatment plant and to maintain the equipment in the plant.*

[6] *Head Loss. An indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, comminutor, filter or other obstruction. The amount of energy or pressure lost is called "head loss." Head loss is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters. In this case, the* HEAD LOSS *is the height to which the water surface must build up in front of the bar screens above the water surface downstream from the bar screens. The build up of water is caused by debris collecting on the bar screen (Figures 4.3 and 4.4).*

[7] *Organic Material. Material which comes mainly from animal or plant sources. Organic material generally can be consumed by bacteria and other small organisms. Inorganic materials are chemical substances of mineral origin.*

[8] *Dissolved Oxygen. Molecular oxygen dissolved in water or wastewater, usually abbreviated DO.*

[9] *Septic (SEP-tick). This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.*

[10] *Hydrogen Sulfide (H_2S). Hydrogen sulfide is a gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls your sense of smell so that you don't notice it after you have been around it for awhile and because the odor is not noticeable in high concentrations. The gas is very poisonous to your respiratory system, explosive, flammable and colorless.*

[11] *Effluent (EF-lu-ent). Wastewater or other liquid – raw, partially or completely treated – flowing* FROM *a basin, treatment process, or treatment plant.*

NOTE: Platform downstream from drain trough that operator stands on to clean bar screen is not shown.

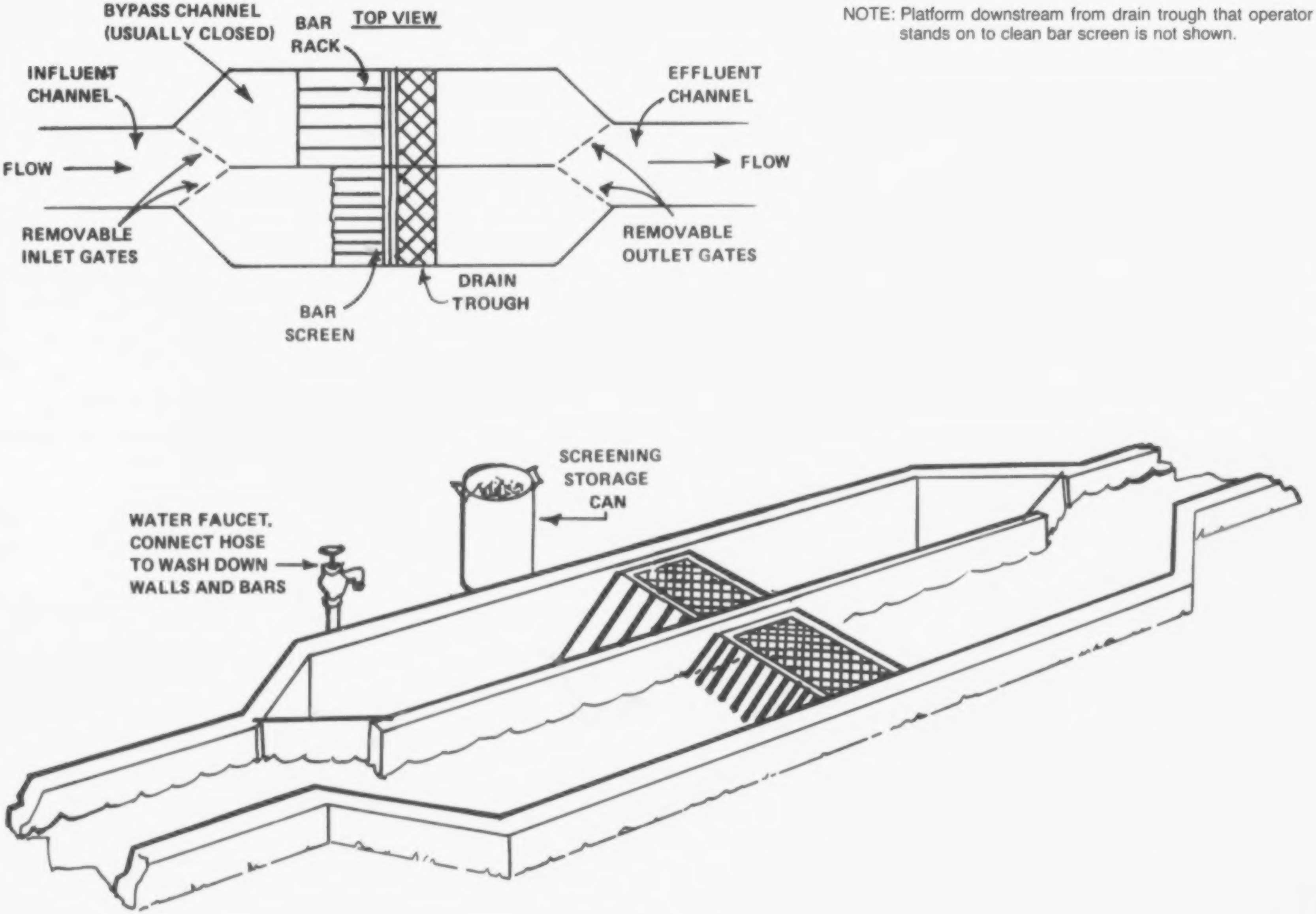
TOP VIEW
BYPASS CHANNEL (USUALLY CLOSED)
BAR RACK
INFLUENT CHANNEL
EFFLUENT CHANNEL
FLOW
FLOW
REMOVABLE INLET GATES
REMOVABLE OUTLET GATES
DRAIN TROUGH
BAR SCREEN
SCREENING STORAGE CAN
WATER FAUCET, CONNECT HOSE TO WASH DOWN WALLS AND BARS

Fig. 4.2 Manually cleaned bar screen installation

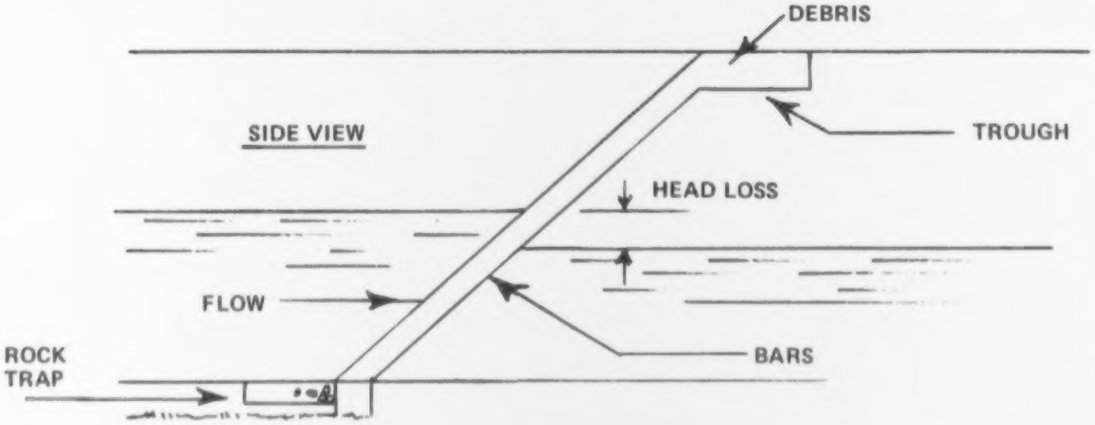
DEBRIS
TROUGH
SIDE VIEW
HEAD LOSS
FLOW
BARS
ROCK TRAP

Fig. 4.3 Manually cleaned bar screen

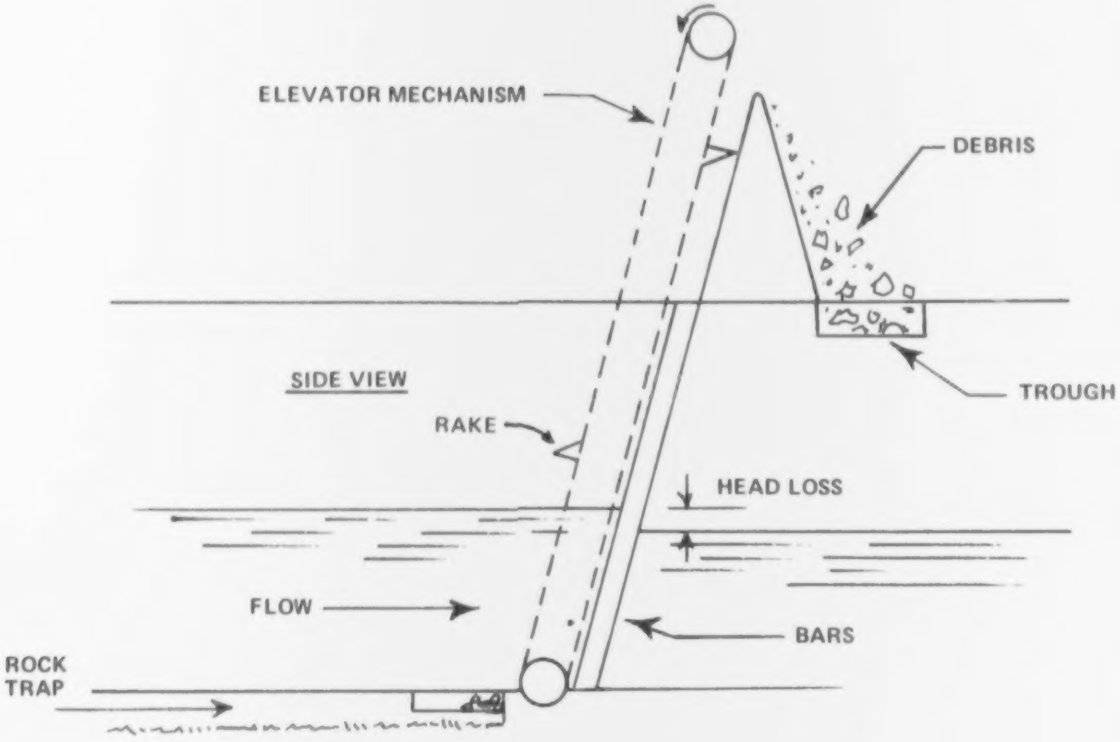
ELEVATOR MECHANISM
DEBRIS
TROUGH
SIDE VIEW
RAKE
HEAD LOSS
FLOW
BARS
ROCK TRAP

Fig. 4.4 Mechanically cleaned bar screen

TABLE 4.1 PURPOSE OF MANUALLY CLEANED BAR SCREENS AND PARTS

Part	Purpose
1. Influent or Inlet Channel	Conveys wastewater to bar racks.
2. Inlet Gate	Selects channel to be used. Inserted in influent channel to prevent flows from reaching screens or racks when they are being maintained or repaired.
3. Bar Screen	Prevents large solids from damaging pumps, plugging pipes or reaching other treatment processes.
4. Bar Rack	Prevents large solids from damaging pumps, plugging pipes or reaching other treatment processes while bar screen is out of service.
5. Outlet Gate	Selects channel to be used. Inserted in effluent channel to prevent flows from reaching screens or racks when they are being maintained or repaired.
6. Drainage Trough	Allows screenings or solids raked from bar screens to drain in order to reduce volume, weight, and moisture content of solids.
7. Screening Storage Can	Container in which to store dried screenings to reduce fly and odor problems until screenings are transported to the disposal site.
8. Rake	Tool used to remove solids or screenings from bar screens.
9. Hose Bib	Provides water under pressure to hose for washing down walls, floor and bar screens.
10. Disposal of Screenings	Screenings may be disposed of by burning, burial on site, or may be hauled off by a waste removal (garbage) company for burial in a sanitary landfill.
11. Gate Storage Rack	Stores inlet and outlet gates when they are not inserted in channels.
12. Platform	Provides safe location where operator can stand and clean bar screen with a rake.

EXTREME CAUTION SHOULD BE TAKEN WHEN RAKING THE SCREEN – FOOTING MAY BE POOR DUE TO THE WATER AND GREASE UNDERFOOT, LACK OF ENOUGH ROOM TO STAND, AND LOCATION OF THE TROUGH OR BUCKET FOR THE DEBRIS. YOU SHOULD INSPECT THIS AREA VERY CAREFULLY TO SPOT HAZARDS AND TAKE CORRECTIVE ACTION. GOOD HOUSEKEEPING, A GUARDRAIL, A HANGER OR OTHER STORAGE FOR THE RAKE, GOOD FOOTING, AND ATTENTION TO OTHER IMPORTANT ITEMS WILL GREATLY REDUCE THE POSSIBILITY OF INJURY.

4.22 Mechanically Cleaned Screens

Mechanically cleaned screens (Fig. 4.4) overcome the problem of wastewater backing up and greatly reduce the time required to take care of this part of your plant. There are various types of mechanisms in use, the more common being traveling rakes which bring the debris up out of the channel and into hoppers or other debris containers. You should keep these units well lubricated and adjusted. Lubrication and adjustment procedures usually will be found in the manufacturer's literature furnished with the equipment. Further information may be found in the plant O & M manual or in the "Maintenance" chapter of this manual. A few minutes spent in proper maintenance procedures can save hours or days of trouble and help to keep your plant operating efficiently.

Occasionally some debris which the equipment cannot remove will be present. Periodic checks should be made so that these materials can be removed manually. To determine if some material is stuck in the screen, lock out power to the unit and divert the flow through another channel or "feel" across the screen with a rake or similar device.

— CAUTION —

Always shut the unit off *FIRST*. *NEVER* reach into the operating range of machinery while it is running. Slow-moving equipment is especially hazardous. Because it moves slowly, it does not appear dangerous. However, most geared-down machinery is so powerful that it can crush almost any obstruction. *A HUMAN HAND, FOR INSTANCE, OFFERS LITTLE RESISTANCE TO THIS TYPE OF EQUIPMENT.*

Other items to watch for with mechanically cleaned screens include observation of the drive units. Adjustments are necessary if the cables do not wind up evenly on the drums of cable machines. A frayed cable or excessively worn chain must be replaced. The equipment should be adjusted if one end of the rake unit is riding higher than the other (causing jamming), if the unit is traveling past its normal stopping position, or if the equipment is jumping or chattering. Frequent hosing or washing down of this equipment will prevent the build up of slimes with resultant odors and flies.

If the rake mechanism will not move, look for two possible causes of the problem:

1. Rake mechanism jammed; or
2. Equipment broken.

When the rake will not move try resetting the circuit breaker. If nothing happens, turn or push equipment switches to off, lock out and tag electrical switches. Divert wastewater to another channel or screen. Look for and remove obstructions which have jammed the rake mechanism.

Whenever a mechanically cleaned bar rack has stalled or the shear pin snapped, be very careful when you attempt to uncouple the chain drive. Be sure to remove a link from the driven side (upper length). This will allow the chain to fly outward and downward towards the floor. *NEVER* remove a link from the lower length because it will fly outward and upward towards *YOU*.

Look for broken equipment when the motor runs but the rack mechanism does not operate. The problem may be caused by a broken chain, cable or *SHEAR PIN*.[12] If the motor is running, the *LIMIT SWITCH*[13] would not be the cause of the problem. To repair or replace a broken part, turn or push equipment switches to off, lock out and tag switches. Divert wastewater to another channel or screen. Perform necessary repairs and place unit in service again. Observe unit for proper operation.

4.23 Operational Procedures

Routine operation of screens and racks will depend on the size of the treatment plant (number of screens and racks), amount of debris in the wastewater, quantity of wastewater, and the head loss across the unit. If the allowable back-up (head loss) of wastewater is not specified in the plant O & M manual, a good starting point is a limit of 3 inches (7.6 cm). Cleaning the screens or racks and changing the number of units in service are basic ways to keep the head loss below or near the desired level and at a minimum. These methods should be used daily and adjustments made to match the flow.

Mechanically cleaned screens may incorporate *AUTOMATIC CONTROLS*[14] that operate the cleaning device whenever the head loss reaches or exceeds a preselected level. Other screen-cleaning devices may operate on a timer which starts the device, allows it to run for a specified time, and then shuts it off for a selected time period. These units usually have a "continuous run" position which allows the device to operate continuously when necessary.

To place a bar rack or screen in service, start up the unit, open the outlet gate, and then open the inlet gate (Fig. 4.2).

To remove a bar rack or screen from service, close or insert the inlet gate and then the outlet gate. Turn the mechanical unit off, drain the channel and wash off the unit. If your plant has two screens in series, one screen may be removed using a hoist, washed off, and returned to service without diverting the flow.

Storms or sewer-cleaning operations by maintenance crews may cause a sudden surge of wastewater and debris and a resultant greater head loss through the screens. Under these conditions, quick action by the operator in adjusting the cleaning frequency and the number of channels or screens in service can prevent such problems as the channels overflowing or wastewater backing up into the sewers. If enough wastewater backs up into the sewers, manhole covers may even pop open and untreated wastewater will be discharged into the streets or back up into homes. Operators must be very alert in these situations.

4.3 DISPOSAL OF SCREENINGS

The material removed from the screens is very offensive and hazardous. This material stinks and attracts rats and flies. Burial or incineration are two common methods of disposal.

The practice of using grinders (shredders, disintegrators) to cut up screenings and return them to the wastewater imposes an increased load on downstream treatment processes, especially surface skimming devices. This problem can be very serious for plants treating combined storm and wastewater flows when the first winter storm transports large amounts of leaves and debris to the treatment plant.

SCREENINGS

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[12] *Shear Pin. A straight pin with a groove around the middle that will weaken the pin and cause it to fail when a certain load or stress is exceeded. The purpose of the pin is to protect equipment from damage due to excessive loads or stresses.*
[13] *Limit Switch. A device that regulates or controls the travel distance of a chain or cable.*
[14] *Automatic controls are discussed in Chapter 15, "Maintenance," and Chapter 8, "Instrumentation," ADVANCED WASTE TREATMENT.*

Depending on plant location and surroundings, you may find it necessary to plan ahead to locate appropriate sites for disposal of screenings. If burial is used, you should estimate how long a certain area can be used before you must find additional space for disposal. The disposal site volume divided by the daily volume of screenings produced will tell you how many days the site will last. For example, assume your plant has a flow of two million gallons per day (MGD) and that over a two-week period you remove an average of *30 GALLONS* of screenings daily. This figures out to *FOUR CUBIC FEET* (cu ft) per day. You bury the screenings each day in a pit which you estimate will hold 15 cubic yards of screenings *IN ADDITION* to the soil used to cover up the screenings.

EXAMPLE 1

(1 cu ft = about 7.5 gallons for practical purposes)[15]

Thus:

$$\begin{aligned}\text{Volume, cu ft/day of Filling Rate} &= \frac{\text{Volume, gal/day}}{7.5\text{ gal/cu ft}}\\ &= \frac{30\text{ gal/day}}{7.5\text{ gal/cu ft}}\\ &= 4\text{ cu ft/day}\end{aligned}$$

You should convert gallons to cubic feet (ft^3 or cu ft) or cubic yards (yd^3, cu yd) because earthwork is figured on this basis. With this information, you are now prepared to estimate how long before the pit will be filled.

FIRST, convert the 15 cu yd (pit) capacity to cu ft:

$$\begin{aligned}\text{Pit Capacity, cu ft} &= \text{Capacity, cu yd} \times 27\ \frac{\text{cu ft}}{\text{cu yd}}\\ &= 15\text{ cu yd} \times 27\ \frac{\text{cu ft}}{\text{cu yd}}\\ &= 405\text{ cu ft}\end{aligned}$$

$$\begin{array}{r} 27\\ \times 15\\ \hline 135\\ 27\\ \hline 405\end{array}$$

SECOND, divide the pit capacity by the daily volume of screenings to find the estimated time before pit is full as follows:

$$\begin{aligned}\text{Time, days} &= \frac{\text{Pit Capacity, cu ft}}{\text{Filling Rate, cu ft/day}}\\ &= \frac{405\text{ cu ft}}{4\text{ cu ft/day}}\\ &= \text{About 101 days.}\end{aligned}$$

Thus you have about 101 days from the time you begin to bury screenings in the pit until you will have to dig another pit provided you consider the amount of soil used to cover up the screenings. You should keep daily records of the volume of screenings buried to be sure it stays about the same. If it increases very much, it could be due to an increase in daily wastewater flow or perhaps some unnecessary disposal of rags or other material into the sewer. You may get anywhere from 0.5 to 12 cubic feet of screenings per million gallons of wastewater flow depending on what people or industry dump into the sewers. This volume per million gallons should stay fairly constant for your plant unless something unusual is happening.

You can check on the daily flow in MGD, or during any time period, by reading your flow totalizer. The totalizer records the total flow through the plant. If you record the totalizer reading at the start and at the end of any time period, the difference is the total flow for that time period.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

4.2A Manually cleaned bar screens should be cleaned frequently to prevent which of the following:

- a. the screen from breaking
- b. septic conditions from developing upstream
- c. a shock load on the plant when eventually cleaned
- d. formation of hydrogen sulfide, which has a rotten egg odor and causes corrosion of concrete and paints
- e. all of these

4.2B What safety precautions should be taken when cleaning a bar screen?

4.2C What should be done *FIRST* if a problem develops in a mechanically cleaned screen?

4.3A How can screenings be disposed of?

4.3B A plant receives a flow of 4.4 million gallons (MG) on a certain day. The day's screenings are calculated to be 11 cubic feet. How many cubic feet of screenings were removed per MG of flow?

4.4 COMMINUTION (com-mi-NEW-shun)

4.40 Comminutors

Comminutors are devices which act both as a cutter and a screen. Their purpose is to shred (comminute) the solids and leave them in the wastewater. This overcomes problems of screenings disposal. As with screens, they are mounted in a channel and the wastewater flows through them. The rags and other cuttable debris are shredded by cutters (teeth) until they can pass through the openings. Pieces of wood and plastic are rejected and remain on the water surface in front of the comminutor. This debris must be removed manually. Most of these units have a shallow pit in front of them to catch rocks and scrap metal. The flow to the comminutor should be shut off periodically and the debris removed from the trap. The frequency of inspecting the trap can be determined from experience. However, it is not wise to allow more than a few days between inspections.

A comminutor consists of a rotating drum with slots for the wastewater to pass through (Figures 4.5, 4.6 and 4.7 and Table 4.2). Other types of comminutors have stationary slotted screens with oscillating cutters mounted on a shaft (Figures 4.8 and 4.9). Cutting teeth are mounted in rows on the drum. The teeth pass through cutter bars or "combs" with very small clearances so that a shearing action is obtained. The wastewater passes into the vertically mounted drum through the slots in the drum and flows out the bottom. A rubber seal, held in place by a bolted-down ring, prevents leakage under the drum. This seal should be checked whenever the rock and scrap metal trap is checked.

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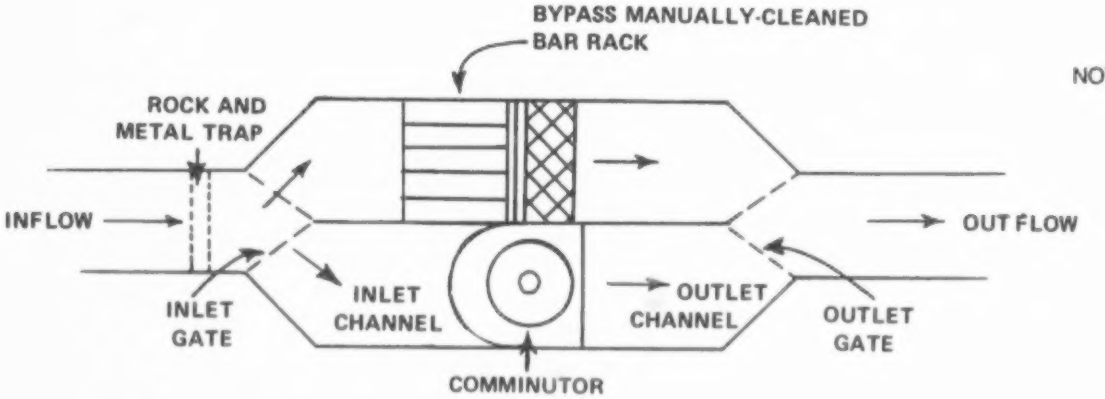
[15] *1 cu ft = about 6.2 Imperial gallons for practical purposes for operators in Canada and other nations using the Imperial gallon.*

NOTE: Platform downstream from drain trough that operator stands on to clean bar rack is not shown.


BYPASS MANUALLY-CLEANED BAR RACK
ROCK AND METAL TRAP
INFLOW
OUT FLOW
INLET GATE
INLET CHANNEL
OUTLET CHANNEL
OUTLET GATE
COMMINUTOR

PLAN OR TOP VIEW

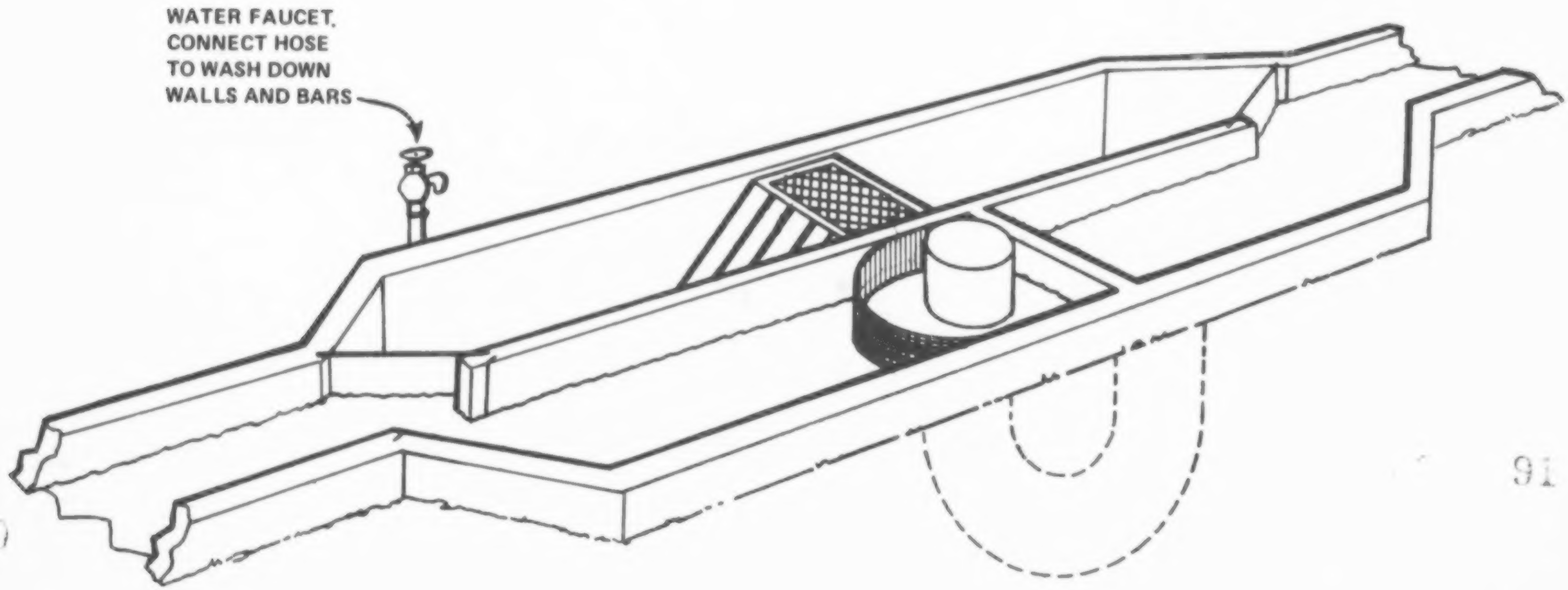

WATER FAUCET, CONNECT HOSE TO WASH DOWN WALLS AND BARS

Fig. 4.5 Comminutor installation

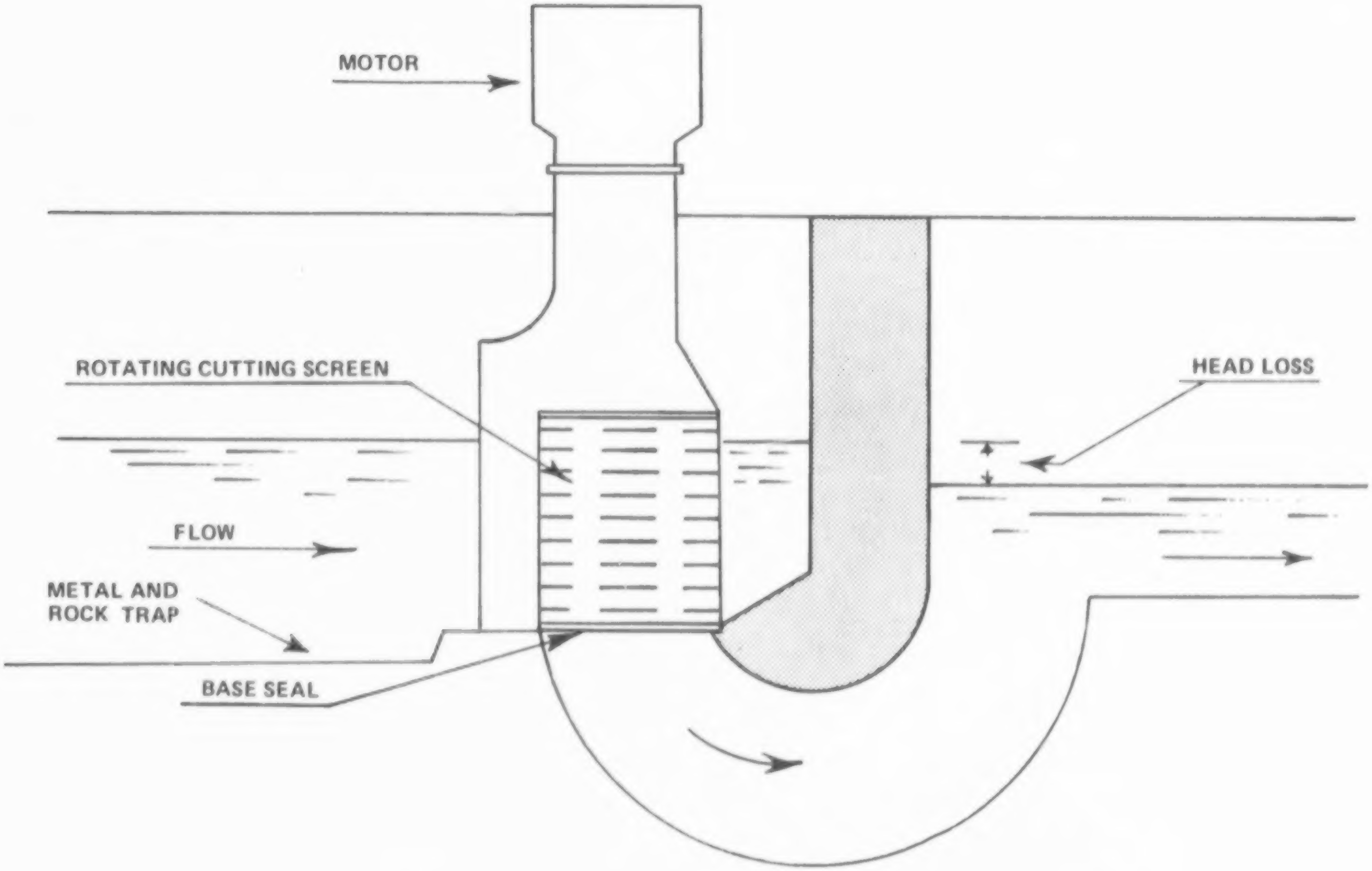
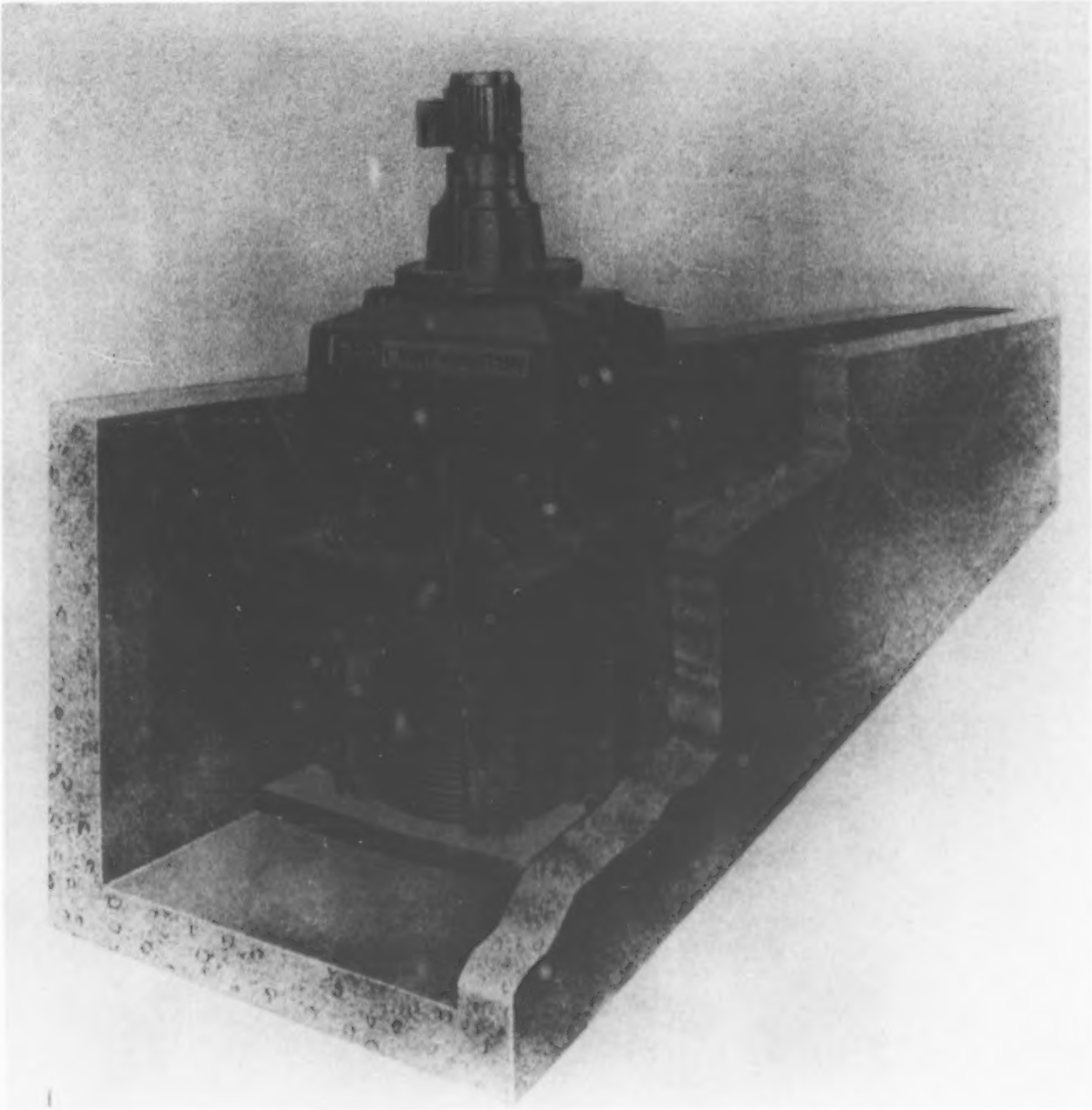

MOTOR
ROTATING CUTTING SCREEN
HEAD LOSS
FLOW
METAL AND
ROCK TRAP
BASE SEAL

Fig. 4.6 Comminutor



NOTE: Cutter rotates 360° around screen.

Fig. 4.7 Comminutor in channel
(Permission of Worthington Pumps, Inc.)

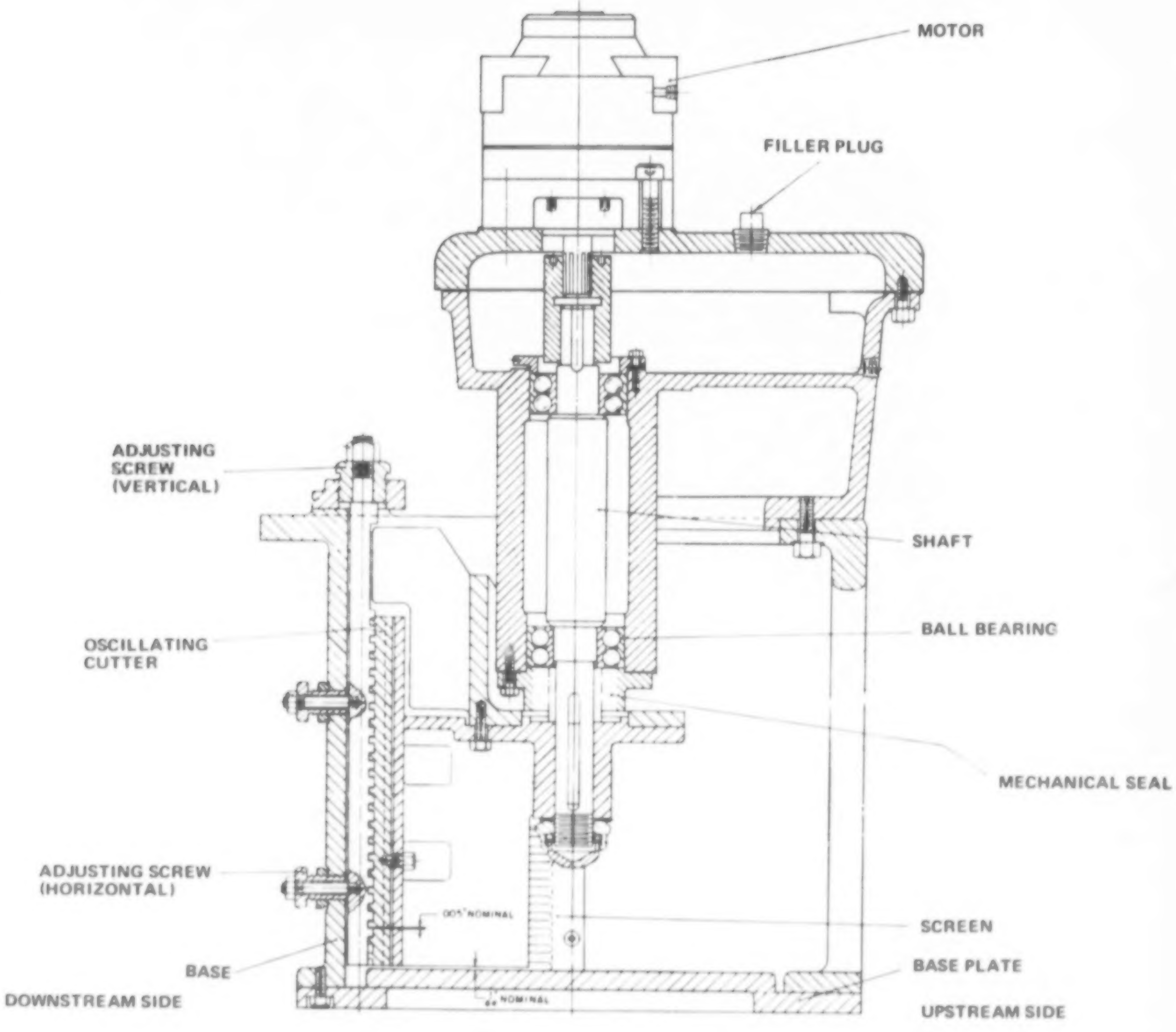

MOTOR
FILLER PLUG
ADJUSTING SCREW (VERTICAL)
SHAFT
BALL BEARING
OSCILLATING CUTTER
MECHANICAL SEAL
ADJUSTING SCREW (HORIZONTAL)
.005" NOMINAL
SCREEN
BASE
BASE PLATE
DOWNSTREAM SIDE
NOMINAL
UPSTREAM SIDE

Fig. 4.8 Comminutor sectional drawing

(Courtesy Worthington Marine & Industrial Products, Inc.)

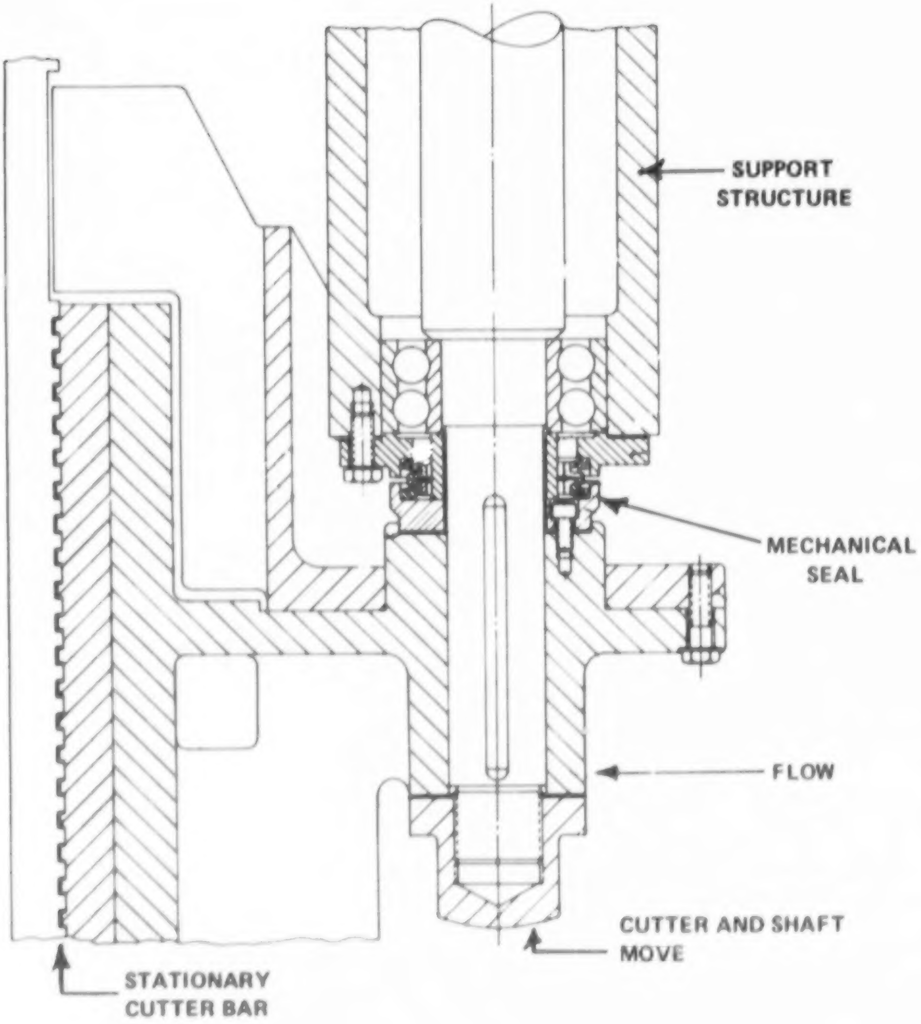

SUPPORT STRUCTURE
MECHANICAL SEAL
FLOW
CUTTER AND SHAFT MOVE
STATIONARY CUTTER BAR

Fig. 4.9 J-Ring bellows type seal

(Courtesy Worthington Marine & Industrial Products, Inc.)

TABLE 4.2 PURPOSE OF COMMINUTORS AND PARTS

Part	Purpose
1. Comminutor	Shreds (comminutes) solids and leaves them in wastewater.
2. Inlet Channel	Conveys wastewater and solids to comminutor.
3. Inlet Gate	Selects channel to be used, diverts wastewater and solids to manually cleaned bar screen, and prevents wastewater flowing to comminutor so equipment can be inspected, maintained, repaired or replaced.
4. Outlet Gate	Prevents wastewater from flowing back to comminutor when equipment is being inspected, maintained, repaired or replaced.
5. Oscillating and Stationary Cutters	Devices containing sharp blades which shred solids.
6. Adjusting Screws	Raises, lowers or moves sideways the cutting blades to provide specified clearances so that a shearing action is achieved.
7. Mechanical Seal	Prevents wastewater from reaching and damaging bearings (Fig. 4.8).
8. Motor and Gear Reducer	Moves cutting blades.
9. Bypass Manually Cleaned Bar Rack	Prevents large solids from damaging pumps, plugging pipes or reaching other plant treatment processes while comminutor is not in service or during peak storm flows.
10. Metal and Rock Trap	Prevents metal and rocks from damaging cutting blades or teeth of comminutor.
11. Platform	Provides safe location where operator can stand and clean bar rack with a rake.

Some older comminutors may have a *MERCURY SEAL*[16] to keep water out of the bearings. This is because these units are designed so that, at their rated capacity, the top of the drum will be under several inches of water. The mercury seal should be checked annually or after a particularly heavy flow. Drain the mercury; weigh it (the amount of mercury will be specified by weight); and if it is dirty, strain it through some heavy material (such as denim or chamois) before putting it back in the comminutor. Add more mercury if needed.

CAUTION
CAUTION
CAUTION

Mercury is poisonous. Breathing the fumes can be fatal or cause loss of hair and teeth. Wash up thoroughly after handling it. Remove gold rings and other jewelry from your hands first, because they may become coated with mercury. If your ring is thus coated, it will have to be heated to burn off the mercury. If you must handle or work with mercury, be sure to work over a large tray in order to catch any spills. Plenty of fresh air ventilation is an absolute *MUST.*

SPECIAL NOTE:

Mercury in water can be oxidized to mercury ions which are toxic to living organisms. Consequently, the Environmental Protection Agency (EPA) has banned the use of mercury seals in comminutors and other applications.

The various manufacturers of equipment using mercury seals have designed conversion kits to provide the necessary water seals by mechanical means. Detailed drawings and instructions are furnished with each conversion kit. It is important that these kits be installed on all mercury-seal type comminutors with a mechanical seal. Details will vary with different companies. Equipment manufacturers furnish service manuals and parts lists with each unit.

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[16] *Mercury seals have been outlawed because of the toxic effects of mercury in the environment. All plants should have replaced all mercury seals with mechanical seals (Fig. 4.8 and 4.9).*

SAFETY

When working around comminutors, use safe procedures and be aware of safety hazards. Wet walkways and dewatered channels are slippery. Take appropriate precautions so you don't slip and fall while attempting to remove floatables which did not pass through the comminutor from the surface of the water.

Never attempt to unplug or unjam the cutter blades without *FIRST* by-passing the unit and then turning off electrical power, locking out switches and placing tags on the switches indicating who did it and when. The moving parts of a comminutor are especially dangerous and can quickly cut off your finger. Do not attempt to repair or troubleshoot electrical equipment and controls unless you are qualified and authorized to do so.

4.41 Barminutors

There are many variations of comminuting devices. One of them has the trade name of "Barminutor" (Figs. 4.10, 4.11 and 4.12 and Table 4.3). This units consists of a bar screen made of U-shaped bars and a rotating drum with teeth and "shear bars." The rotating drum travels up and down the bar screen. Careful attention must be given to maintaining the oil level in these machines; otherwise, water may get into the bearings. Cutting edges on the cutter should be sharpened or replaced at regularly scheduled intervals. The frequency of maintenance depends on the type and abrasiveness of the wastewater being treated.

Careful attention to preventive maintenance procedures will save you a lot of trouble. Use the manufacturer's instructions, the Maintenance chapter, and the plant O & M manual to become thoroughly familiar with the equipment in your plant. When *ALL* lubrication points and oil levels are properly maintained and *ALL* adjustments and clearances are correct, the equipment may be expected to give long and trouble-free service.

If you are operating an old plant and the manufacturer's literature is no longer available, try to develop a maintenance program that appears suited for the equipment. Old records should provide you with an indication of how the equipment was maintained in the past and if the procedures worked. If nothing is available, try inspecting oil levels weekly and changing oil every 90 days with SAE 90.

TABLE 4.3 PURPOSE OF BARMINUTORS AND PARTS

Part	Purpose
1. Barminutor	Shreds solids and leaves them in wastewater.
2. Bar Screen	Retains large solids in wastewater for shredding by rotating cutter.
3. Rotating Cutter	Moves up and down bar screen and shreds solids retained on bar screen.
4. Motor and Gears	Turns rotating cutter and moves rotating cutter up and down bar screen.
5. Counterweight (Not all models have counterweights)	Reduces the energy required by the motor to move the rotating cutter up and down the bar screen.

Safe practices which apply to working around comminutors also apply to barminutors. Treat the rotating drum with respect because it could easily cut you. Normal and abnormal operational procedures as well as start-up and shutdown procedures for barminutors are similar to those used for comminutors.

4.42 Operational Procedures

Routine operation of comminutors and barminutors (comminution units) is basically the same as the operation of screens and racks. The main factors are the number of units, the amount of debris in the wastewater, and the head loss through the unit. Look up the allowable head loss through the unit in the manufacturer's literature or the plant O & M manual. Where two or more comminution units are available, keep enough units operating to stay within the head loss limits.

Sudden high flows or heavy amounts of debris (resulting from industrial dumps, sewer line maintenance or storm flows) may require prompt action to avoid having wastewater back up into the sewers or overflow the channels. Automatic controls on some equipment may take care of most of these situations.

In some plants a bypass channel (with a bar rack) is provided to relieve high flow conditions and problems during down time on the comminution unit while it is being cleaned or serviced. The debris from the bar rack may be returned to the comminution unit's influent (a little at a time) after the unit is back in service.

Starting up or shutting down comminutors and barminutors is done the same way as for mechanically cleaned screens. When starting up a unit, first turn on the equipment, then open the outlet gate and finally open the inlet gate. Always read manufacturer's instructions first because some units require the inlet gate to be open before starting. Observe the unit to see that it appears and sounds to be operating properly.

To shut down a comminution unit, reverse the procedure. After shut down, drain the channel and hose down the channel and the equipment to reduce problems from odors and flies.

Daily, or more often if experience indicates, shut down each unit to look for cans and other debris and to check for "ropes" of rags hanging from the slotted drums or "U" bars. Presence of this type of debris indicates that the cutters may be worn or out of adjustment. If the motor stops (kicks out), it may be another indication of dull or improperly adjusted cutters. If the debris is not cut when the cutters mesh, this causes an overload on the drive motor.

On barminutors, look for accumulations of sand and gravel that could interfere with the travel of the drum. Other possible problems include overtravel and on some models, difficulties with the cables. Overtravel occurs when the cutter drum travels too far up or too far down and reaches the bottom of the channel. Usually overtravel occurs when the limit switches on the cable drums fail to work properly and permit excessive travel and cable unwinding from the drum. If this happens cables may not wind back up on the drum evenly after unwinding. This will cause the cutter drum to travel at an angle across the screen, thus damaging both the cutters and the screen bars. Be sure that the unit stays level when it moves up and down, that the cables wind evenly on the drums, and that the cables are not frayed. A cable malfunction can result in major damage to the barminutor.

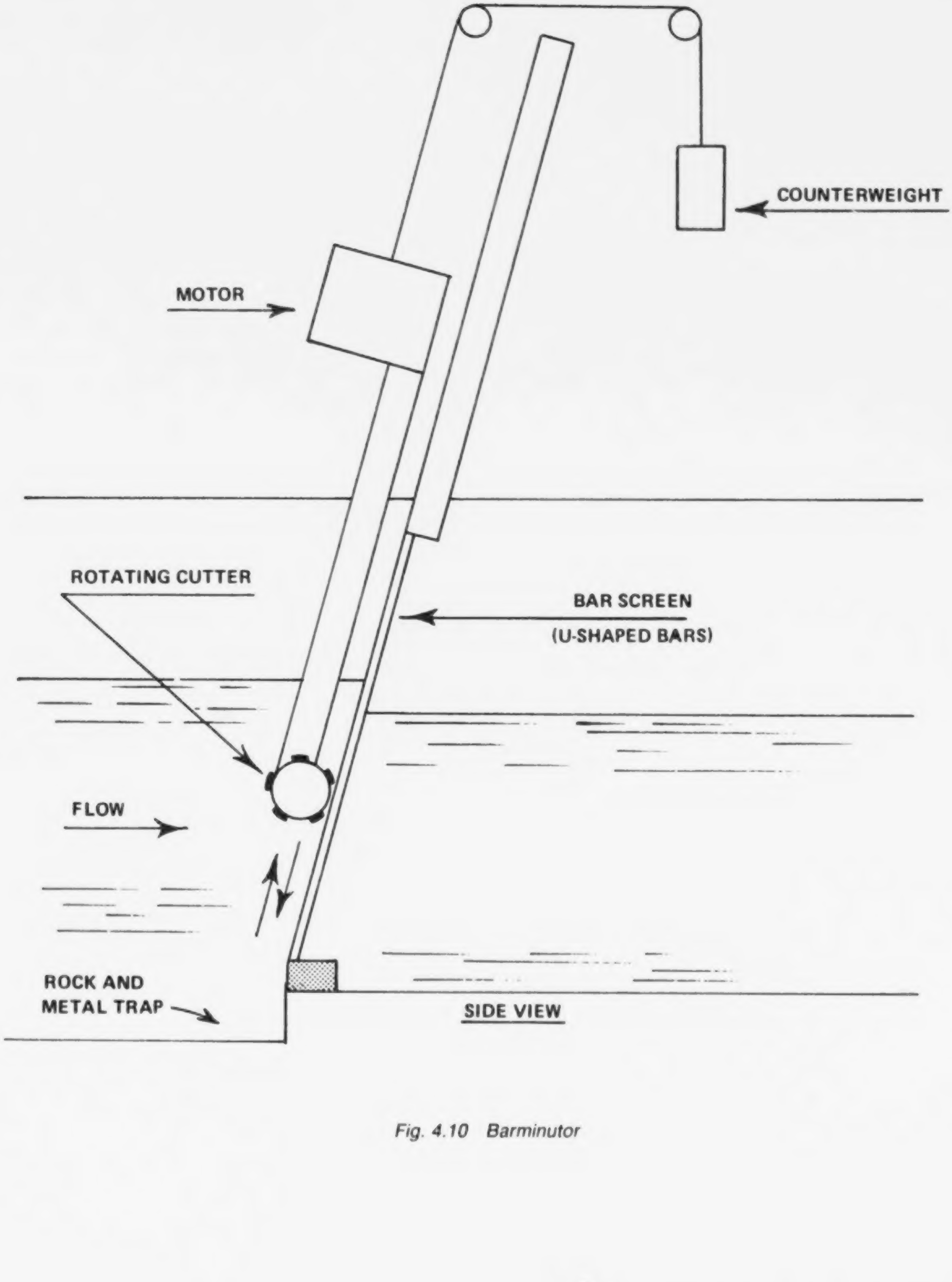

COUNTERWEIGHT
MOTOR
ROTATING CUTTER
BAR SCREEN
(U-SHAPED BARS)
FLOW
ROCK AND
METAL TRAP
SIDE VIEW

Fig. 4.10 Barminutor

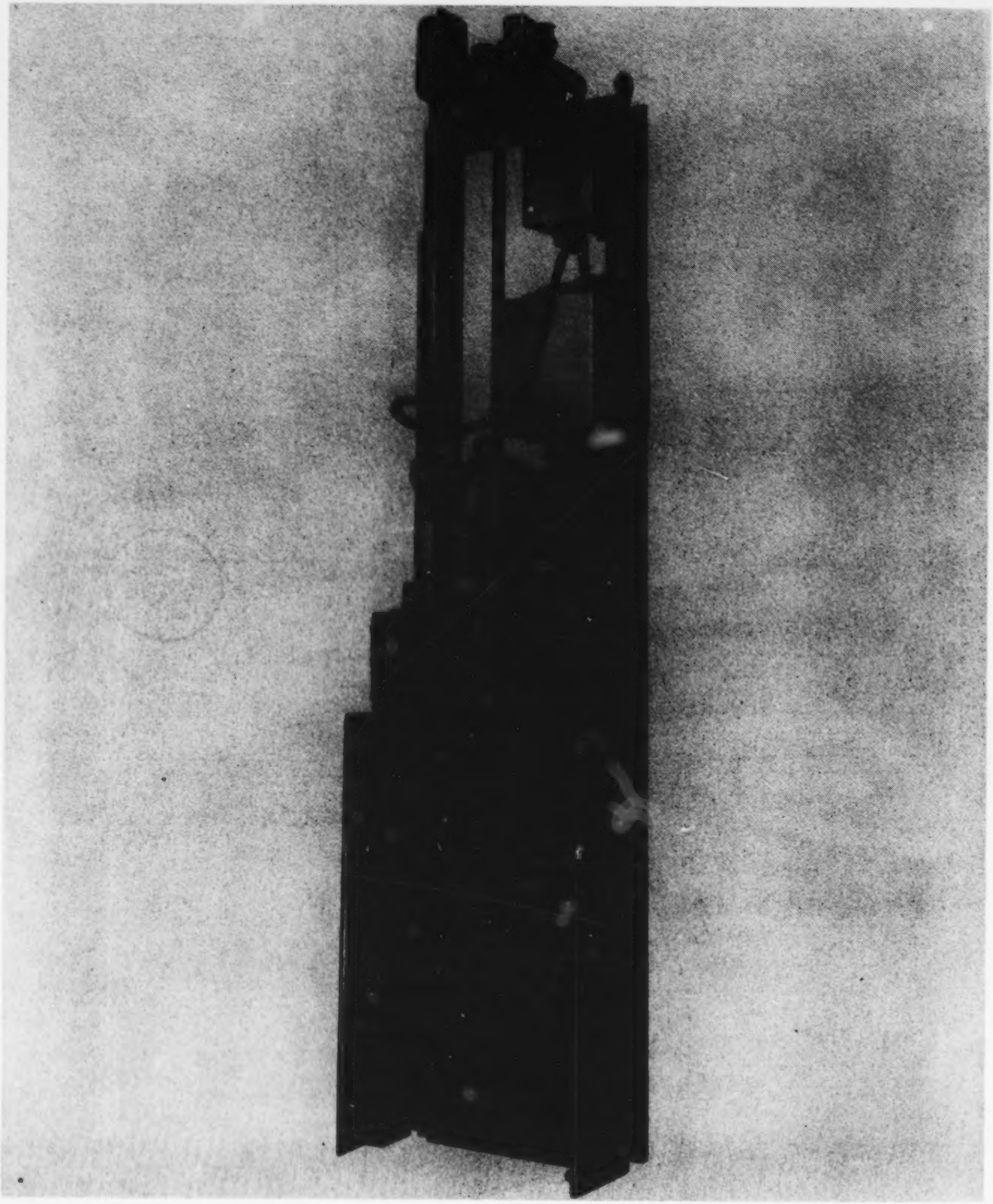


Fig. 4.11 Barminutor

(Permission of FMC Corporation, Environmental Equipment Division)

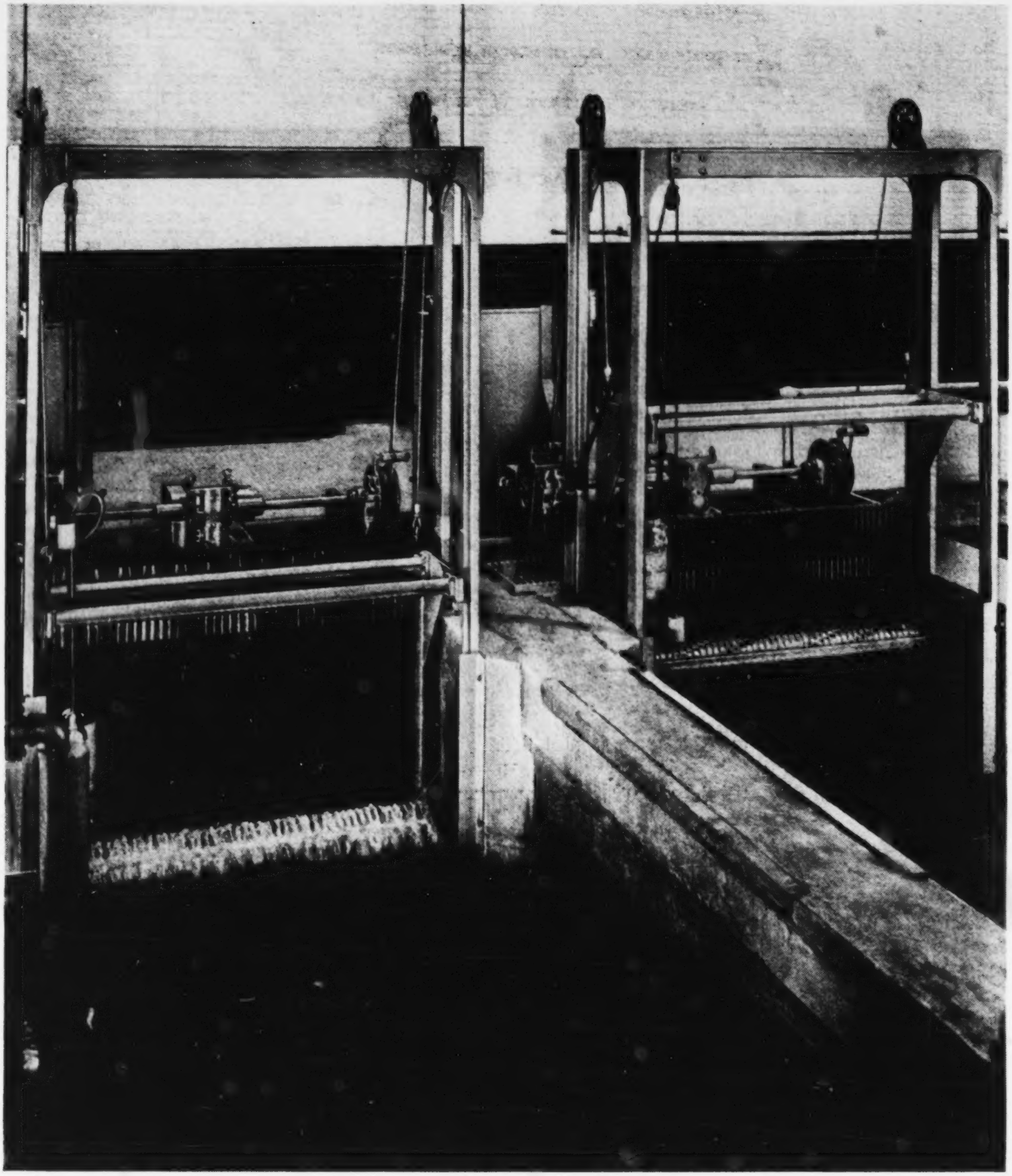


Fig. 4.12 Barminutor installation

(Permission of FMC Corporation, Environmental Equipment Division)

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 95.

4.4A What are the advantages of comminuting machines over screens?

4.4B What has replaced mercury seals in comminutors?

4.4C Why is it hazardous to handle mercury?

a. It is poisonous.
b. Breathing fumes may be fatal.
c. Breathing fumes may cause loss of hair and teeth.
d. All of the above.

4.4D How are comminution units different from bar racks and bar screens?

4.5 GRIT REMOVAL

Grit (sand, eggshells and cinders) is the heavier mineral matter which is found in wastewater and will not decompose or "break down." This material causes excessive wear in pumps. A mixture of grit, tar, grease and other cementing materials can form a solid mass in pipes and digesters. This mass will not move and cannot be removed by ordinary means. Consequently, grit should be removed as soon as possible after reaching the plant.

4.6 GRIT CHANNELS (Fig. 4.13 and Table 4.4)

The simplest means of removing grit from the wastewater flow is to pass it through channels or tanks which allow the velocity of flow to be reduced to a range of 0.7 to 1.4 ft/sec (0.2 to 0.4 m/sec). The objective is to allow the grit to settle to the bottom while keeping the lighter organic solids moving along to the next treatment unit. Experience has shown that a flow-through velocity of one foot per second (ft/sec) is best.

Velocity is controlled by several means. With multiple-channel installations, the operator may vary the number of channels (chambers) in service at any one time to maintain a flow velocity of approximately one ft/sec in the grit channels. Another involves the use of proportional weirs (Fig. 4.14) at the outlet for automatic regulation.

TABLE 4.4 PURPOSE OF GRIT CHANNELS AND PARTS

Part	Purpose
1. Grit Channel	Provides a reduction in flow velocity. The lower velocity allows grit to settle to the bottom while keeping the lighter organic solids moving along to the next treatment unit.
2. Grit Settling Area	Provides space for grit to settle, accumulate and be removed.
3. Center Wall	Separates grit channels.
4. Slide or Inlet Gates	Regulates number of grit channels in service in order to maintain desirable flow velocities in grit channels.
5. Stop or Outlet Gates	Prevents backflow. Insert when cleaning.
6. Weirs	Controls velocity in grit channel.
7. Grit Storage or Grit Hopper	Accumulates and stores grit before removal and disposal.
8. Dewatering Drain	Drains grit channel for inspection, cleaning and repairs.
9. Drain Valve	Allows draining of grit channel.

The proportional weir in Fig. 4.14 will tend to *MAINTAIN* the velocity in the grit channels when the flows increase. This happens because the exit area will decrease, thus increasing the depth of water flow in the channel in direct proportion to the flow.

Flow velocities also may be regulated by the shape of the grit channels. Some grit channels have cross-sectional shapes similar to that of a proportional weir. The operator also may regulate the velocities in a grit channel by using bricks or cinder blocks to change cross-sectional shape or area. However, this can cause cleaning, maintenance and operational problems.

A simple method for estimating the velocity is to place a stick in the channel and record the time it takes for the stick to travel a measured distance. Calculate as follows:

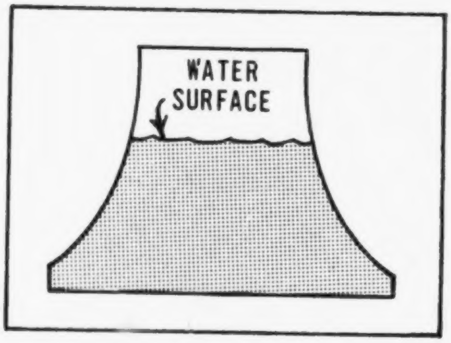


Fig. 4.14 Proportional weir

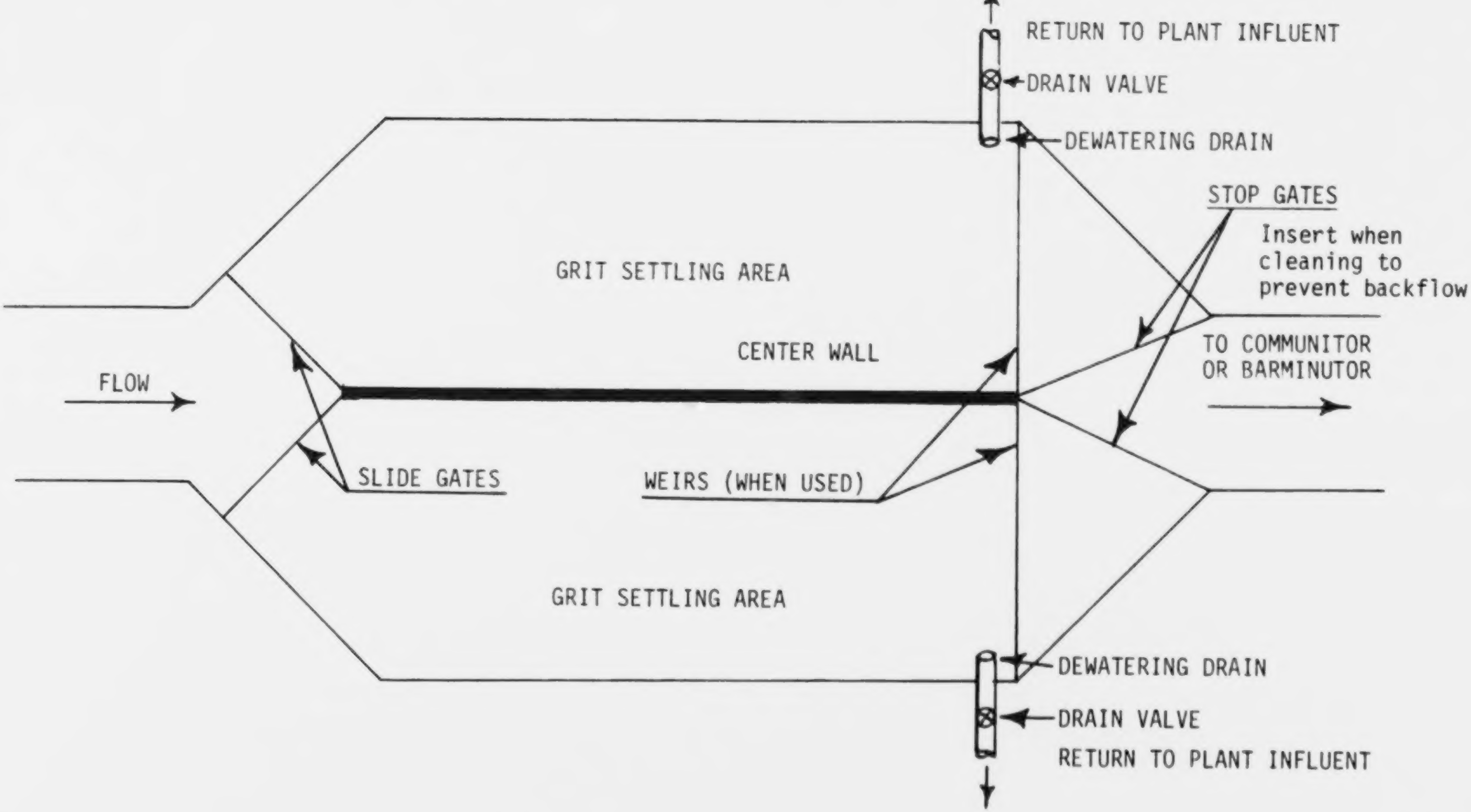

RETURN TO PLANT INFLUENT
DRAIN VALVE
DEWATERING DRAIN
STOP GATES
Insert when cleaning to prevent backflow
GRIT SETTLING AREA
CENTER WALL
TO COMMUNITOR OR BARMINUTOR
FLOW
SLIDE GATES
WEIRS (WHEN USED)
GRIT SETTLING AREA
DEWATERING DRAIN
DRAIN VALVE
RETURN TO PLANT INFLUENT

Fig. 4.13 Grit channel

$$\text{Velocity, ft/sec} = \frac{\text{Distance Traveled, ft}}{\text{Time, sec}}$$

EXAMPLE 2

A stick travels 25 feet in 20 seconds.

Solution:

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Distance, ft}}{\text{Time, sec}}\\ &= \frac{25\text{ ft}}{20\text{ sec}}\\ &= 1.25\text{ ft/sec}\\ &\quad (0.38\text{ m/sec})\end{aligned}$$

$$\begin{array}{r} 1.25 \\ 20\overline{)25.00} \\ \underline{20} \\ 5\,0 \\ \underline{4\,0} \\ 1\,00 \\ \underline{1\,00} \\ 0 \end{array}$$

The actual velocity probably will be slightly higher than your estimate, but this is a very quick way to estimate the grit channel velocity.

A more accurate method for determining the average velocity in the grit channel is based on:

1. The cross-sectional area of the flow in the grit channel; and
2. The quantity of flow (from the flow meter).

The formula for calculating grit channel velocity is shown in the following example.

EXAMPLE 3

Assume your grit channel is two feet wide. The wastewater is flowing at a depth of one foot, and the flow meter registers a flow of 1 MGD. The cross-sectional area of the flow is (depth, ft × width, ft = 1 ft × 2 ft) = 2 sq ft. The flow must be converted into cubic measure. We learned that one cubic foot equals 7.5 gallons. Thus, from calculations below, 1 MGD = 1.55 cu ft/sec (cubic feet per second, cfs):

$$1\text{ MGD} = \frac{(1{,}000{,}000\ \frac{\text{gal}}{\text{day}})}{(7.5\ \frac{\text{gal}}{\text{cu ft}} \times 24\ \frac{\text{hr}}{\text{day}} \times 60\ \frac{\text{min}}{\text{hr}} \times 60\ \frac{\text{sec}}{\text{min}})} = 1.55\text{ cfs}$$

Using this new conversion factor:

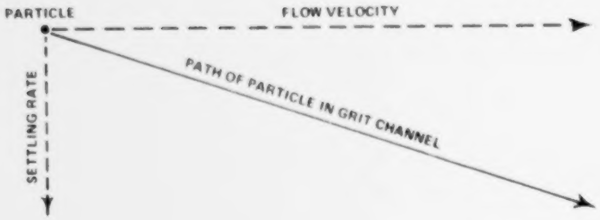
$$\begin{aligned}\text{Average Velocity, ft/sec} &= \frac{\text{Flow Rate, cu ft/sec}}{\text{Area, sq ft}}\\ &= \frac{1.55\text{ cu ft/sec}}{2\text{ sq ft}}\\ &= 0.77\text{ ft/sec (0.23 m/sec)}\end{aligned}$$

To obtain this answer, we converted the flow from MGD to cu ft/sec. Then we divided the flow (1.55 cu ft/sec) by the cross-sectional area of the wastewater in the channel (2 sq ft).

EXAMPLE 4

Since we have checked the velocity, we should now determine if the length of the channel is appropriate for our flow conditions. All particles settle at different rates based on their size and weight. Most grit channels are designed to remove 0.2 mm (millimeter) size sand and all other heavier materials. Experiments have shown this size particle will settle downward at about 0.075 ft/sec. This means that, if wastewater is flowing in a channel at a depth of one foot and a particle of 0.2 mm is introduced at the surface, it will take:

$$\begin{aligned}\text{Settling Time, sec} &= \frac{\text{Depth, ft}}{\text{Settling Rate, ft/sec}}\\ &= \frac{1\text{ ft}}{0.075\text{ ft/sec}}\\ &= 13.3\text{ seconds to settle}\end{aligned}$$



If this waste were flowing at one foot per second, it would travel for 13.3 seconds, or a distance of 13.3 feet, before the particle reached the channel bottom. If the waste were flowing at a depth of three feet in the channel, it would take 13.3 seconds/ft × 3 ft = 39.9 seconds or 39.9 feet before the particle reached the bottom. Therefore, the required length of any grit channel can be checked by using the formula:

$$\text{Length, ft} = \frac{(\text{depth of channel, ft})\ (\text{flow velocity, ft/sec})}{(\text{settling rate, ft/sec})}$$

and for 0.2 mm sand and a flow velocity of 1 ft/sec:

$$\begin{aligned}\text{Length, ft} &= \frac{(\text{depth, ft})\ (1.0\text{ ft/sec})}{(0.075\text{ ft/sec})}\\ &= \frac{1.0 \times \text{depth, ft}}{0.075}\\ &= 13.3 \times \text{depth, ft}\end{aligned}$$

In case of dead spots where organic materials settle out and become *PUTRESCIBLE*,[17] a deflector (Fig. 4.15) installed at one side may cure the trouble. (Be sure you don't create a new dead spot.) Also, certain trouble spots could be filled in with concrete.

Methods of grit removal range from use of a scoop shovel to various types of collectors and conveyors. For manually cleaned channels, the frequency of cleaning is determined by experience. If the grit builds up too much, it may interfere with the flow-through velocity, cause the wastewater to back up into the sewer or may cause an overflow. The channel should be removed from service during the cleaning operation. This makes the job easier and no grit is washed into the downstream treatment processes.

Since there is always a small amount of organic matter in the grit channel, disposal of grit should be treated the same as disposal of screenings. Burial is the most satisfactory disposal method. Failure to quickly cover grit with six inches (15 cm) of soil results in odors and attracts flies and rats.

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[17] *Putrescible (pew-TRES-uh-bull). Material that will decompose under anaerobic conditions and produce nuisance odors.*

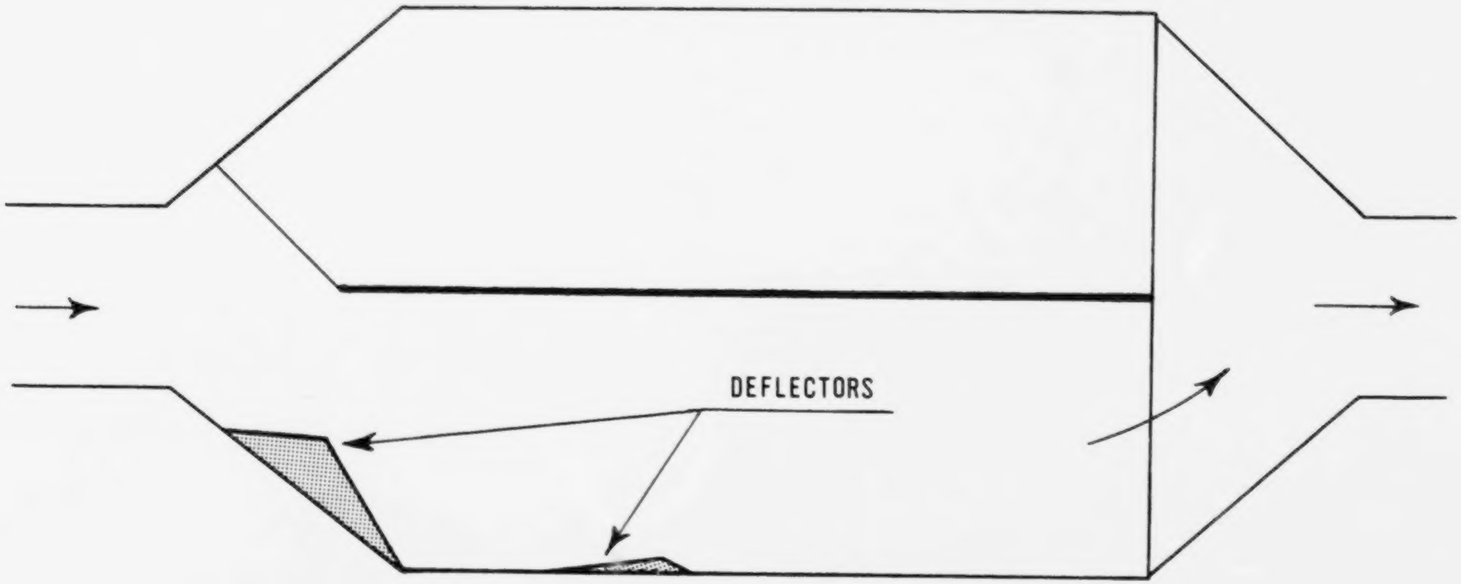
DEFLECTORS

Fig. 4.15 Deflectors installed in a grit channel

CLEANING GRIT CHANNELS MANUALLY CAN BE QUITE HAZARDOUS. TAKE PRECAUTIONS AGAINST SLIPPING AND BACK STRAIN. BEWARE OF DANGEROUS GASES WHEN WORKING IN COVERED GRIT CHANNELS.

There are many types of mechanical grit-collector mechanisms. Common ones are chain-driven scrapers called "flights" (Fig. 4.16) that are moved slowly along the bottom and up an incline out of the water to a hopper, or along the bottom to an underwater trough where a screw conveyor lifts the grit to a storage hopper or truck. Some designs use conveyor belts with buckets attached.

Before starting or diverting wastewater into a grit channel, be sure the channel or settling area is clear of debris, tools and people. If the grit channel has scrapers or flights, start them and observe smooth and proper operation before diverting the wastewater into the channel. Once the flow is going through the grit channel, measure the velocity. Make any necessary adjustments in the number of channels in service and adjust the weirs or other velocity-regulating devices.

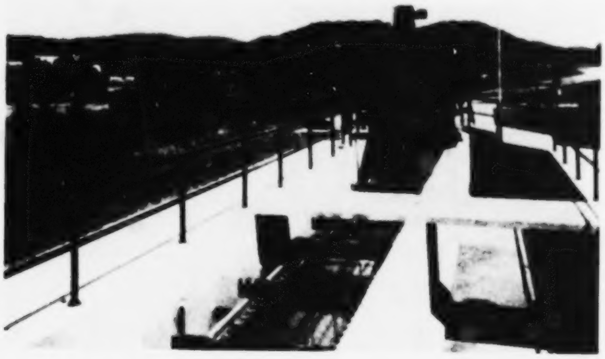

Fig. 4.16 Chain-driven scrapers (flights)

(Courtesy Jeffrey Mfg. Co.)

Normal operation consists of measuring velocities at low, average, and high flows. To achieve desired velocities, maintain the proper number of grit channels in service and adjust the weirs.

Grit should be removed on a daily basis. Inspect the grit for organic material which could indicate that velocities are too low. If less than expected amounts of grit are removed and the grit consists mainly of large or heavy sand, the velocities could be too high. A little organic matter in the grit usually indicates that proper velocities are being maintained.

Abnormal operating conditions can develop during rain storms or periods of heavy snow melt. Peak canning seasons or periodic industrial dumps also can create abnormal conditions. Operating problems also occur during periods of high flows and when solids loadings become excessive. During these conditions, attempt to maintain velocities as close to 1.0 ft/sec (0.3 m/sec) as possible. Grit will have to be removed more frequently when the grit and heavy solids loadings are higher than usual.

Try to schedule grit channel shutdowns during periods of low flows. Shut down grit channels for maintenance or repairs by placing alternate or additional grit channels in service if possible. Insert sludge or inlet gate and stop outlet gate. Open the drain valve and dewater the grit channel. Be careful the drain does not plug. Wash out or hose down the floor of the grit channel before entering. Dewatered grit channels have slippery bottoms; so walk and work carefully.

Maintenance of grit channels consists of keeping the facilities clean and inspecting for corrosion damages and cracks in the walls and floor. Corrosion rates can be retarded by the application of protective coatings. In channels with chain and flight collectors inspect chains and sprockets for excessive wear at least twice a year and bearings and anchor bolts every time the channel is dewatered. Motors must be lubricated and greased in accordance with the manufacturer's recommendations.

An *AERATED* grit chamber is actually a tank with a sloping bottom and a hopper or trough in the lower end (Fig. 4.17 and Table 4.5). Air is injected through *DIFFUSERS*[18] located along the wall of the tank above the trough. The mixture of air and water has a lower *SPECIFIC GRAVITY*[19] than water so the grit settles out better. The rolling action of the water in the tank moves the grit along the bottom to the grit hopper. Grit is removed from the hopper by pumps or a conveyor system.

Aerated grit chambers are most frequently found at activated sludge plants where there is a readily available air supply, and the preaeration usually helps to "freshen" the wastewater. The older wastewater becomes, the more difficult it is for aerobic organisms to treat wastes and for solids to settle. A freshening process tends to make downstream treatment processes more effective.

To start an aerated grit chamber, be sure all equipment works properly and the grit chamber contains no debris or tools. Start air passing through the diffuser. Allow wastewater to enter the aerated chamber slowly. Adjust the air flow rates to obtain the desired circular motion in the grit chamber. Air rates also are regulated to control the size of grit and the volume of grit removed from the wastewater.

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[18] *Diffuser.* *A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles.*

[19] *Specific Gravity.* *Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles usually have a specific gravity of 0.5 to 2.5.*

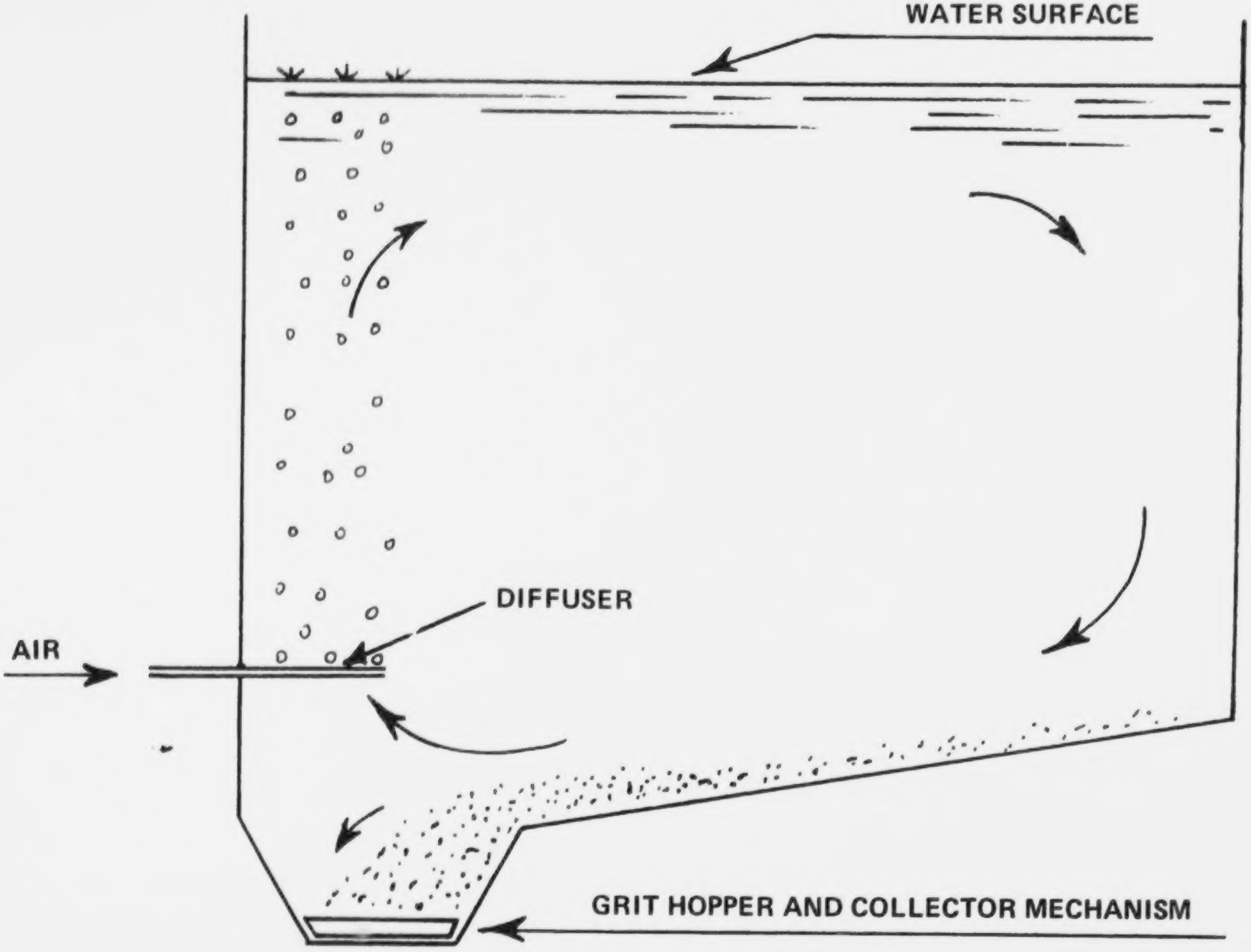
WATER SURFACE
DIFFUSER
AIR
GRIT HOPPER AND COLLECTOR MECHANISM

Fig. 4.17 Aerated grit chamber

TABLE 4.5 PURPOSE OF AERATED GRIT CHAMBER AND PARTS

Part	Purpose
1. Aerated Grit Chamber	Removes grit.
2. Diffuser	Disperses air into wastewater to reduce velocities. The mixture of air and water has a lower specific gravity than water so the grit settles out better. The circular motion created by the air moves the grit to the bottom of the chamber where it can settle out.
3. Grit Hopper	Collects settled grit before removal.
4. Collector Mechanism	Removes grit from chamber for disposal. Other grit collector mechanisms include screw conveyors, buckets or pumps.

Aerated grit chambers usually have a detention time of approximately three minutes at peak flows with detention times ranging from three to five minutes.

The velocity of roll or agitation regulates the size of particles of a given specific gravity that will be removed in the grit chamber. If the velocity of roll is too great, grit will be carried out of the chamber. If the velocity of roll is too low, organic material will be removed with the grit. With proper adjustment of the quantity of air, almost 100 percent grit removal can be obtained and the grit should be well washed. Wastewater should move through the grit chamber in a circular (helical) path and should make two to three passes across the bottom of the tank at peak flows. There should be more passes across the bottom at lower flows. Wastewater should be introduced into the grit chamber in the direction of flow.

Normal operation consists of maintaining hydraulic capacity (design flow) through each chamber and the desired circular motion. Remove grit at regular intervals or continuously from the grit hopper depending on the equipment and also on the grit loading. If scum and floating debris accumulate on the surface in dead areas, remove this material twice a day, or more often if needed.

When abnormal operating conditions exist due to high flows or heavy solids loadings, adjust air flow to the tank to maintain the desired grit removal at the operating conditions experienced. If grit and solids are not removed, they may be carried over to the primary clarifiers. If so, increased primary sludge pumping rates or more frequent or longer pumping times may be necessary.

Shutdown procedures consist of diverting wastewater flows around the aerated grit chamber, draining the facility and stopping the air supply. Draining is not necessary during temporary shutdown, such as taking a unit out of service during low flows.

4.7 CYCLONE GRIT SEPARATORS

Another method of separating grit from organic matter is by the use of cyclone grit separators (Fig. 4.18 and Table 4.6). Grit from mechanically cleaned grit channels or other grit removal facilities is pumped as a *SLURRY*[20] in water to the cyclone. The velocity of the slurry as it enters along the wall of the cyclone causes the slurry to spin or swirl around the inside of the cyclone. This is called the "primary vortex" (Fig. 4.19). The particles of grit, being heavier than the wastewater, are forced outward to the casing of the cyclone. The grit spirals downward towards the apex or bottom of the cyclone. At the bottom, the heavier particles (grit) pass out of the cyclone through a small hole called an "orifice." The remaining lighter particles and water are carried upward (still spinning in what is called the "secondary vortex") and out the overflow. The primary vortex causes the heavy particles to move towards the wall of the cyclone and out the bottom. The secondary vortex moves the lighter particles towards the center of the cyclone and out the top.

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[20] *Slurry (SLUR-e). A thin, watery mud, or any substance resembling it (such as a grit slurry or a lime slurry).*

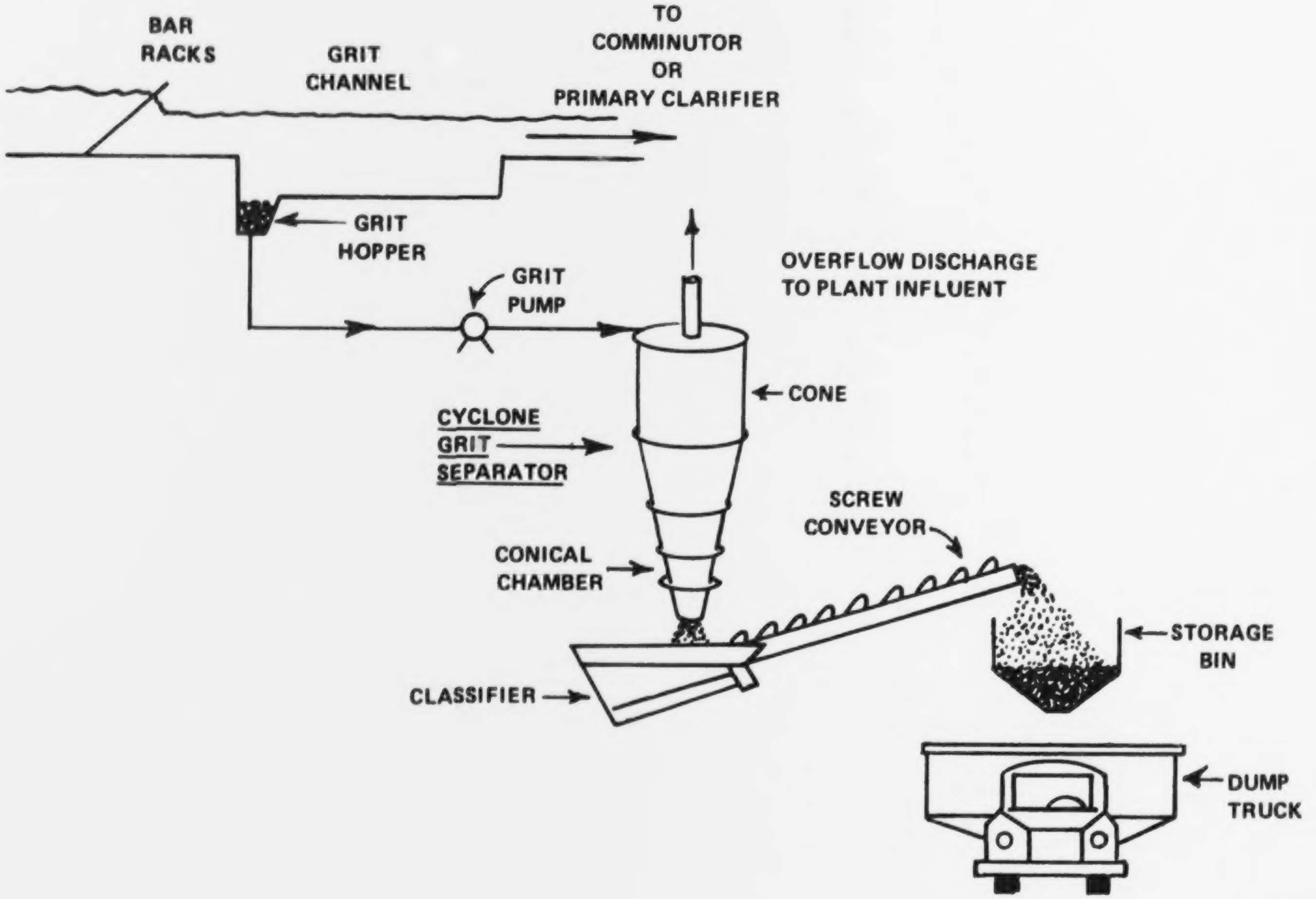
BAR RACKS
GRIT CHANNEL
TO COMMINUTOR OR PRIMARY CLARIFIER
GRIT HOPPER
GRIT PUMP
OVERFLOW DISCHARGE TO PLANT INFLUENT
CONE
CYCLONE GRIT SEPARATOR
SCREW CONVEYOR
CONICAL CHAMBER
STORAGE BIN
CLASSIFIER
DUMP TRUCK

Fig. 4.18 Cyclone grit separator

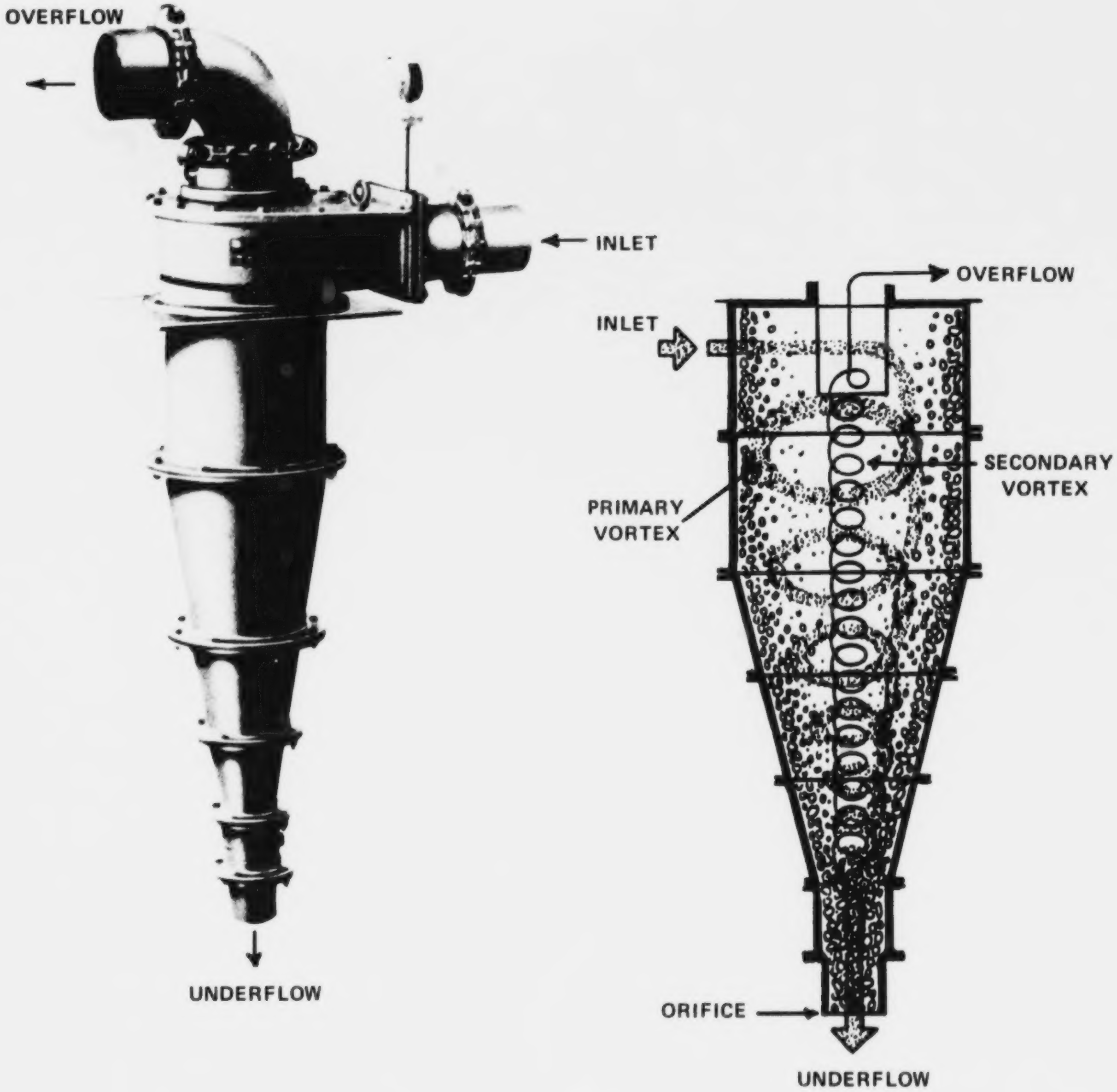
OVERFLOW
INLET
UNDERFLOW
OVERFLOW
INLET
SECONDARY VORTEX
PRIMARY VORTEX
ORIFICE
UNDERFLOW

Fig. 4.19 How a grit cyclone separator works

(Permission of WEMCO Division, Envirotech Corporation)

The grit is usually removed from a grit classifier at the bottom of the cyclone by means of a screw conveyor to storage hoppers. Ultimately the grit is hauled away and buried at a disposal site.

4.70 Safety

Working around and on cyclone grit separators requires the exercise of extreme caution. Always shut off, lock out and tag equipment before attempting to remove objects causing stoppages or to work on the equipment. Slowly-moving screw conveyors and other equipment can seriously injure you by crushing or tearing your hand or leg. Sometimes the lifting of heavy cyclone parts is required from very difficult positions which could result in sprains or strains if you are not careful. In these situations, hoists or ropes should be used whenever possible. Be very cautious on slippery surfaces because a fall may result in a serious injury.

4.71 Start Up

Prior to initial start up of a cyclone grit separator, inspect the area and facilities for tools and debris. Pump water to the unit to see that the piping is clear and that the pressure gage and other equipment all function properly.

Normal operation start ups involve starting the grit conveyor and then the pumps. Once the separator is operating, make the necessary adjustments as discussed in the next section under *OPERATION*.

4.72 Operation

FEED: The amount of water being pumped with the grit is important. In general, dilute feed slurries will allow separation of smaller particles. Thicker slurries will result in a slower rotational motion and reduced capacity. Inlet pressure is critical and should be maintained as close as possible to manufacturer's recommended pressure.

UNDERFLOW DISCHARGE: The underflow discharge from the bottom (apex) should appear as a hollow cone shape. If the discharge is too heavy, it appears as a rotating solid spiral (looks like a rope) and a heavily overloaded condition will appear as a straight stream lacking spiral motion. No underflow could mean the feed slurry is too thick or debris (such as rags) has plugged the apex.

FEED INLET PRESSURE AND OVERFLOW DISCHARGE: The inlet pressure affects efficiency and must be maintained within the limits prescribed by the manufacturer. The overflow discharge is through an adjustable orifice called the "vortex finder" (Fig. 4.20). Inlet pressure and overflow discharge are closely related functions. The optimum settings may be found quickly by making the adjustments just discussed while observing the operation of the unit.

4.73 Shutdown

To remove the cyclone grit separator from service, shut down the facility by turning off the supply pump which feeds the cyclone.

Allow the cyclone to drain. Hose down and wash out overflow discharge, grit classifier and screw conveyor. Turn off grit classifier and screw-drive motor.

4.74 Maintenance

Maintenance consists of applying procedures outlined in your plant O & M manual and manufacturer's literature for maintenance of the cyclone, grit pump, screw conveyor and screw conveyor drive motor. The cyclone liner and screw conveyor must be replaced when excessive wear prevents proper adjustments and the equipment no longer functions as intended.

TABLE 4.6 PURPOSE OF CYCLONE GRIT SEPARATOR AND PARTS

Part	Purpose
1. Cyclone Grit Separator	Separates grit from wastewater and organic material.
2. Grit Pump	Pumps grit from hopper to cyclone grit separator.
3. Entrance Chamber	Introduces grit to cyclone.
4. Conical Chamber	Provides enclosed vessel (tank) where grit is separated from water and organic matter.
5. Overflow Discharge Pipe	Carries wastewater and organic matter back to plant influent.
6. Grit Classifier	Removes organics from grit by washing.
7. Screw Conveyor	Moves grit from grit hopper under cyclone to grit storage bin.
8. Grit Storage Bin	Stores grit until loaded into dump truck for hauling to disposal site.
9. Screw Conveyor Drive Motor	Turns screw conveyor.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 95 and 96.

4.5A Grit is composed mostly of which of the following substances?

a. Grease
b. Sand
c. Rubber Goods
d. Eggshells
e. Wood

4.5B Why bother to remove grit?

4.6A How can you control the velocity in a grit channel in order to maintain velocities within a range of approximately 0.7 to 1.4 fps?

4.6B A stick travels 20 feet in 40 seconds in a grit channel.

a. What is the velocity in the channel?
b. What corrective action should be taken, if any?

4.6C List the safety hazards that might be encountered while manually cleaning a grit channel.

4.6D Assume you wish to calculate the velocity in the grit channel at your plant's peak flow. Examining the flow charts, you determine that peak flows are usually about 2.75 MGD. The grit channel is three-feet wide, and the flow depth is 17 inches at peak flow. What is the velocity in the grit channel under these conditions?

4.7A What is the purpose of a cyclone grit separator?

4.7B List the possible safety hazards an operator may encounter when working around a cyclone grit separator.

4.8 GRIT WASHING

A grit channel with a slower flow velocity than recommended may allow large quantities of organic matter to settle out with the grit. This heavy, coarse mixture of grit and organic material is called *DETRITUS*.[21] In some plants grit channels are called "detritus tanks." Organic matter may be separated from the grit by washing the detritus to re-suspend the organic matter.

In some cases the grit is used as fill material. Under these conditions it is necessary to wash the grit. Figure 4.20 shows a typical grit washer, and the purposes of the parts are summarized in Table 4.7. Grit settles to the bottom and is removed by a screw conveyor (or other device), while the velocity created by the impeller suspends the lighter organic materials so that they flow over the outlet weir.

When working around a grit washer, avoid slippery areas where you could slip and fall or even slip into the grit washer. Always turn off, lock out and tag the controls of the screw conveyor before attempting to remove stuck material and to inspect or repair the screw conveyor.

Before pumping grit or wash water to a grit washer, be sure both the screw conveyor and screw-type impeller work properly. Under normal operating conditions, pump grit to the washer at regular intervals as necessary. Operate the screw conveyor during the grit-washing operation. When the grit-washing procedure is completed, turn off the equipment.

To shut down the grit washer for inspection, maintenance or repairs, drain the facility and wash down the walls and conveyor. Treat the empty washer as an enclosed space and provide adequate ventilation. Be sure two people carefully observe anyone who enters an empty grit washer for any reason in order to rescue this person if necessary. Before entering, test the area for toxic gases (hydrogen sulfide), sufficient oxygen and explosive conditions. Wear a safety harness and have a self-contained breathing apparatus nearby for rescue purposes.

Maintenance consists of inspecting the entire facility for corrosion damages and examining moving parts for wear. Oil and grease the facilities in accordance with plant O & M manual and manufacturer's instructions.

TABLE 4.7 PURPOSE OF GRIT WASHER AND PARTS

Part	Purpose
1. Grit Washer	Washes organic material out of grit and sand.
2. Inlet Chamber	Mixes grit and wash water and introduces mixture into grit washer.
3. Wash Water	Helps separate organic material from grit and sand.
4. Screw-Type Impeller	Circulates contents of grit washer and brings water and separated organics to surface of washer for removal.
5. Motor	Turns screw-type impeller.
6. Outlet	Removes water and organics from grit washer.
7. Screw Conveyor	Conveys grit from bottom of grit washer to hopper for transfer to truck for disposal.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

4.8A Why is it necessary or desirable to "wash" grit?

4.8B List the maintenance steps for a grit washer.

4.9 QUANTITIES OF GRIT

Treatment plants having well-constructed separate wastewater collection systems can usually expect to average 1 to 4 cu ft of grit per million gallons.[22] These quantities have been rising in recent years due to household garbage grinders. They can also be expected to increase during storm periods.

Plants receiving waste from combined collection systems can expect to average 4 to 15 cu ft of grit per million gallons with peaks many times higher during storm periods. Grit collected during storm periods has been reported at over 500 cu ft per million gallons, probably the result of flow from broken sewers or open channels.

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[21] *Detritus (dee-TRI-tus). The heavy, coarse mixture of grit and organic material carried by wastewater.*

[22] *Uniform reporting of results is important. Everyone should use the same units. You should obtain a copy of the Water Pollution Control Federation Manual of Practice No. 6,* UNITS OF EXPRESSION FOR WASTEWATER TREATMENT, *and use the units as recommended. The manual can be obtained from the Water Pollution Control Federation, Publications Order Department, 601 Wythe Street, Alexandria, VA 22314-1994. Order #M00060. Price $6.00 for WPCF members and $8.00 for others, plus $3.75 postage and handling.*

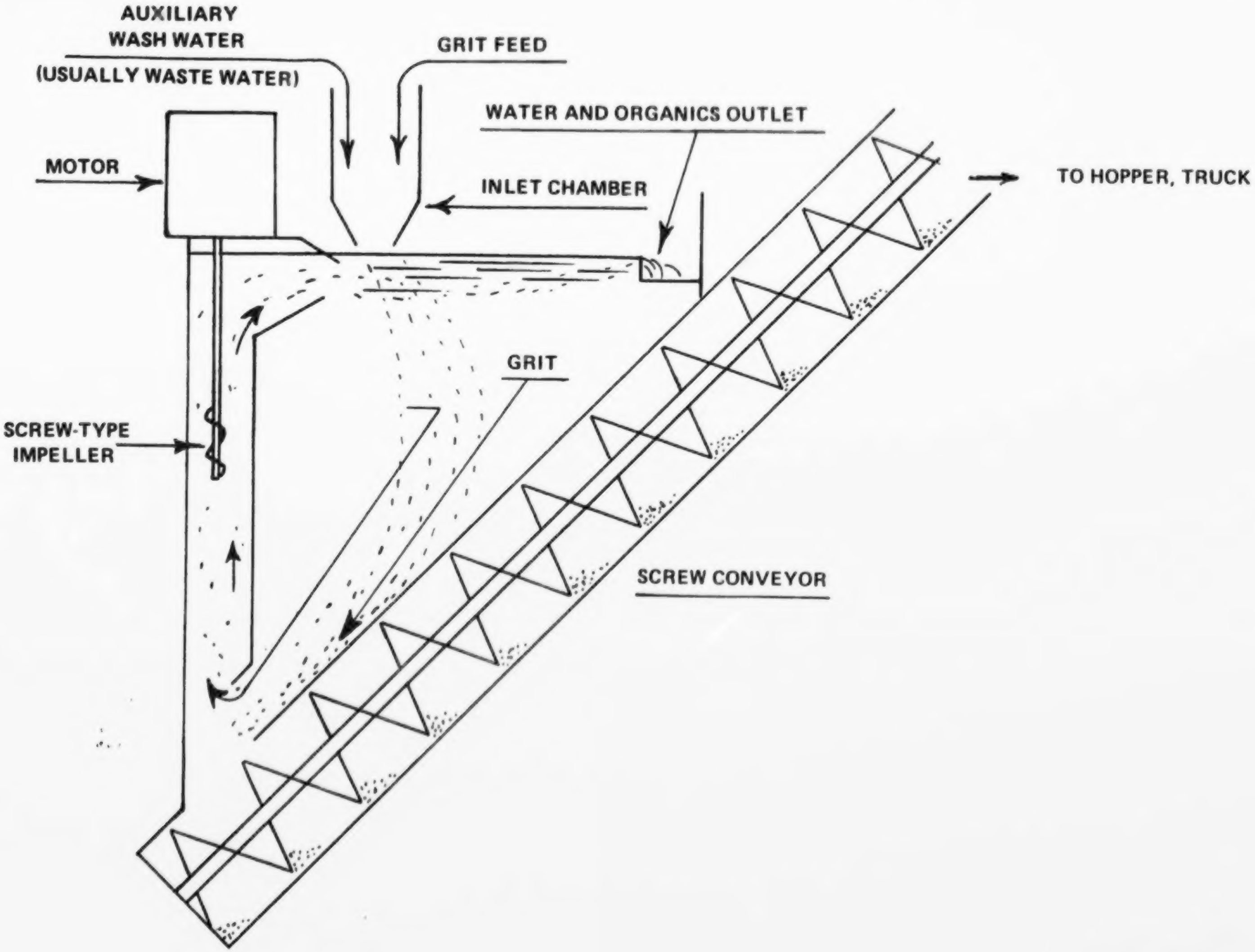
AUXILIARY
WASH WATER
(USUALLY WASTE WATER)
GRIT FEED
WATER AND ORGANICS OUTLET
MOTOR
INLET CHAMBER
TO HOPPER, TRUCK
GRIT
SCREW-TYPE
IMPELLER
SCREW CONVEYOR

Fig. 4.20 Grit washer

Records of grit quantities should be kept in the same manner as for screenings.

QUESTION

Write your answers in a notebook and then compare your answers with those on page 96.

4.9A Your plant has an average flow of 2.0 MGD. An average of 4 cu ft of grit is removed each day. How many cu ft of grit per MG of flow are removed?

4.10 DISPOSAL OF GRIT

Final disposal of grit is by burial. This may be in a sanitary landfill or other types of landfill operations. Regardless of the method, at least 6 inches (15 cm) of soil should be placed over the grit to keep out rats and flies.

4.11 PRE-AERATION

Pre-aeration is a wastewater treatment process used to help grit removal, to freshen wastewater, to remove gases, to add oxygen, to promote flotation of grease, and to aid coagulation. The freshening of wastewater improves the effectiveness of downstream treatment processes. The pre-aeration process is usually located before primary sedimentation (Fig. 4.1). Other processes used to accomplish freshening include *OZONIZATION*[23] and prechlorination.

Pre-aeration consists of aerating wastewater in a channel or separate tank for 10 to 45 minutes. Aeration may be accomplished by either mechanical surface aeration units or diffused air systems.[24] Air application rates with a diffused air system normally range from 0.5 to 1.0 cu ft of air per gallon of wastewater (3.75 to 7.5 cu m air/cu m wastewater) treated.

4.12 OPERATIONAL STRATEGY

This chapter has covered basic concepts in the operation and maintenance of equipment used to remove grit, rags, coarse materials and other debris from the wastewater before it enters the treatment plant. Now let's consider some things to do and to watch for when a piece of equipment breaks down or the plant becomes overloaded by excessive flows.

If screens or comminutors are overloaded or bypassed, you can expect the following problems:

1. Sticks and rags can foul the raw sludge pumps for the primary clarifiers;
2. Debris can plug the orifices in trickling filter distributors;
3. Debris can interfere with air diffusers in the aeration tanks of activated sludge plants;
4. Floating debris can appear in the chlorine contact basin and leave the plant in the final effluent; and
5. Solids can plug return sludge pumps and flow meters in activated sludge plants.

If grit channels are bypassed or overloaded, grit can reach the primary clarifiers. To reduce resulting problems, increase the pumping of raw sludge to keep the clarifier hopper, piping, and pumps from plugging.

You can get into other types of trouble by increasing pumping unless your plant is equipped with sludge thickeners. Overpumping from the clarifier will affect the digesters. The grit will occupy valuable space; the extra water will lower the temperature of the digesters or require more energy for heating and may wash the *ALKALINITY*[25] *BUFFER*[26] out of the digester. Also, excessive amounts of supernatant from the digesters will add to the organic load on the plant. Therefore, if you are faced with this problem, you should look for ways to relieve and/or to avoid the problem in the future. For example, the raw sludge or digester supernatant could be pumped to a standby tank or pond whenever the grit channels must be bypassed or are overloaded.

To remove floating debris from chlorine contact basins and the final effluent, try hand skimming with hardware cloth nets. Also hardware cloth screens may be installed in the clarifier effluent troughs and final effluent channel.

These problems and possible actions to take show how important it is for the operator to do everything possible to keep pretreatment equipment well maintained. Obviously, breakdowns of pretreatment equipment may be expected to cause a

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[23] *Ozonization (O-zoe-nie-ZAY-shun). The application of ozone to water, wastewater, or air, generally for the purposes of disinfection or odor control.*

[24] *See Chapter 8, "Activated Sludge," for a discussion of aeration facilities.*

[25] *Alkalinity (AL-ka-lin-ity). The capacity of water or wastewater to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.*

[26] *Buffer. A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.*

lot of problems throughout the plant. In spite of good operation and maintenance, failures may still occur.

You should consider what to do when you have a failure at your plant. You must plan in advance what to do to correct the situation or to adjust the other treatment processes. For example, you can have screens made and emergency storage facilities prepared to handle wastewater bypasses and overflows. Advance preparation for emergencies can save a lot of extra work and make it possible to keep your plant operating efficiently under unfavorable circumstances.

4.13 DESIGN REVIEW

When reviewing plans and specifications, operators can be very helpful to design engineers, by thinking of how they plan to operate and maintain each treatment process and facility. This section lists a few items operators should study on plans for expansion of existing facilities or construction of new treatment plants.

4.130 Racks and Screens

1. Is there room for a rake when removing screenings? Will the handle of the rake hit any buildings, overhead wires, light posts or overhead lights?
2. Is there provision for a good standing place that won't become slippery?
3. Is there some place to drain and store screenings?
4. Where is the disposal site for the screenings?
5. How many channels and racks or screens are there, and what is the capacity of each? What will happen during peak storm flows?
6. What are the standby units?
7. What are the Operation and Maintenance (O & M) requirements of the facilities?
8. Are there provisions for a hoist for removal of screenings if facility is located below grade?
9. Is there an adequate dock facility for loading containers on a truck for disposal?
10. Is there adequate water under sufficient pressure to hose down machinery and area?
11. Are sufficient spare parts provided in accordance with manufacturer's recommendations?

4.131 Grit Removal

1. Are there guard rails around the grit chambers or grit channels?
2. Are there provisions for taking the grit channels or grit chambers out of service and for draining?
3. How many channels will be required for average and wet weather flows? What will happen during peak storm flows?
4. Are there standby units if there are high flows or if one unit is out for repairs during a storm?
5. How easily can the units be cleaned?
6. Can the grit hoppers be flushed easily?
7. Are there grit storage facilities and are they adequate?
8. Are there grit dewatering capabilities?
9. Are there provisions for skimming floatables from water surfaces?
10. Have items 8 through 11 in Section 4.130, "Racks and Screens" been checked for this Section too?

4.132 Wet Wells

1. Explosion-proof wiring should be installed in areas such as the wet well, screening room, and any other enclosed space. Floating fuels such as gasoline or fuel oil can enter a wet well, evaporate, and form an explosive mixture with air. Significant amounts of fuel may enter a sanitary sewer system unintentionally by being dumped or drained into a storm sewer system which is part of a combined collection system or through underground fuelline leaks. *EXPLOSIMETERS*[27] are strongly suggested because they can sound an alarm before explosive conditions are reached.
2. Ventilation is very important to control toxic gases and corrosion, as well as explosive conditions. Forced air circulation creates a positive air pressure on wastewater in a wet well and tends to keep toxic gases in solution. This procedure is considered superior to an exhaust gas system.
3. If floating oils can be expected in influent wastewaters, skimmers can be helpful in wet wells.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 96.

4.12A What kinds of problems can be created for the operator when screens or comminutors are overloaded or bypassed?

4.13A What items would you check when reviewing the plans and specifications for racks and screens?

4.14 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read all of Section A.4, Metric System.

In Section A.13, Typical Wastewater Treatment Plant Problems, read and work the problems in the following sections:

1. A.130 Flows, and
2. A.131 Grit Channels.

4.15 ADDITIONAL READING

1. *MOP 11*, Chapter 6, "Screening" and Chapter 7, "Grit Removal."*
2. *NEW YORK MANUAL*, Chapter 3, "Preliminary Treatment."*
3. *TEXAS MANUAL*, Chapter 9, "Screens, Grinders, Grit Chambers and Grease Traps."

* Depends on edition

4.16 METRIC CALCULATIONS

This section contains the solutions to all problems in this chapter using metric calculations.

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[27] *Explosimeters. Instruments used to detect explosive atmospheres. When the Lower Explosive Limit (L.E.L.) of an atmosphere is exceeded, an alarm signal on the instrument is activated.*

4.160 Conversion Factors

MGD × 3785 = cu m/day
cu m/day × 0.000 264 = MGD
gallons × 3.785 = liters
liters × 0.264 = gallons
1000 *L* = 1 cu m
ft × 0.3048 = m
m × 3.281 = ft
cu ft × 28.32 = liters
L × 0.035 315 = cu ft

4.161 Problem Solutions

1. A wastewater treatment plant receives a flow of 8000 cubic meters per day. During a two-week period you remove an average of 120 liters of screenings daily. Screenings are buried in a pit which will hold 12 cubic meters of screenings *IN ADDITION* to the soil used to cover up the screenings. How many days will the site last?

Known		Unknown
Flow, cu m/day	= 8000 cu m/day	Time to Fill Pit, days
Screenings, *L*/day	= 120 *L*/day	
Pit Capacity, cu m	= 12 cu m	

1. Calculate the filling rate of the pit in cubic meters per day.

$$\text{Filling Rate, cu m/day} = \text{Screenings, } L\text{/day} \times \frac{1 \text{ cu m}}{1000\ L}$$

$$= 120\ L\text{/day} \times \frac{1 \text{ cu m}}{1000\ L}$$

$$= 0.12 \text{ cu m/day}$$

2. Estimate the time to fill the pit.

$$\text{Time to Fill Pit, days} = \frac{\text{Pit Capacity, cu m}}{\text{Filling Rate, cu m/day}}$$

$$= \frac{12 \text{ cu m}}{0.12 \text{ cu m/day}}$$

$$= 100 \text{ days}$$

2. Estimate the velocity in a grit channel if a stick travels 10 meters in 25 seconds.

Known		Unknown
Distance, m	= 10 m	Velocity, m/sec
Time, sec	= 25 sec	

1. Estimate the velocity in the grit channel.

$$\text{Velocity, m/sec} = \frac{\text{Distance, m}}{\text{Time, sec}}$$

$$= \frac{10 \text{ m}}{25 \text{ sec}}$$

$$= 0.4 \text{ m/sec}$$

3. A grit channel is one meter wide and the wastewater is flowing at a depth of 0.5 meters. The flow is 10,000 cubic meters per day. Estimate the velocity in the grit channel in meters per second.

Known		Unknown
Width, m	= 1 m	Velocity, m/sec
Depth, m	= 0.5 m	
Flow, cu m/day	= 10,000 cu m/day	

1. Convert flow from cubic meters per day to cubic meters per second.

$$\text{Flow, } \frac{\text{cu m}}{\text{sec}} = \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$= 10{,}000 \ \frac{\text{cu m}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$= 0.116 \text{ cu m/sec}$$

2. Determine area of grit channel.

$$\text{Area, sq m} = \text{Width, m} \times \text{Depth, m}$$

$$= 1 \text{ m} \times 0.5 \text{ m}$$

$$= 0.5 \text{ sq m}$$

3. Estimate velocity in meters per second.

$$\text{Velocity, m/sec} = \frac{\text{Flow, cu m/sec}}{\text{Area, sq m}}$$

$$= \frac{0.116 \text{ cu m/sec}}{0.5 \text{ sq m}}$$

$$= 0.23 \text{ m/sec}$$

4. Determine the desired length of a grit channel if the depth is 0.5 meters and the particle settling velocity is 0.023 meters per second. The flow velocity is 0.23 meters per second.

Known		Unknown
Depth, m	= 0.5 m	Grit Channel Length, m
Settling Vel, m/sec	= 0.023 m/sec	
Flow Vel, m/sec	= 0.23 m/sec	

1. Calculate the desired length of the grit channel.

$$\text{Length, m} = \frac{(\text{Depth of Channel, m})(\text{Flow Vel, m/sec})}{\text{Settling Velocity, m/sec}}$$

$$= \frac{(0.5 \text{ m})(0.23 \text{ m/sec})}{0.023 \text{ m/sec}}$$

$$= 5 \text{ m}$$

5. A wastewater treatment plant has an average flow of 8,000 cubic meters per day. An average of 0.12 liters of grit is removed each day. How many liters of grit are removed per cubic meter of flow?

Known		Unknown
Flow, cu m/day	= 8,000 cu m/day	Grit Removed, *L*/cu m
Grit, *L*/day	= 0.12 *L*/day	

1. Calculate the grit removed in liters of grit per cubic meter of flow.

$$\text{Grit Removed, } L\text{/cu m} = \frac{\text{Grit Removed, } L\text{/day}}{\text{Flow, cu m/day}}$$

$$= \frac{0.12\ L\text{/day}}{8000 \text{ cu m/day}}$$

$$= 0.000\ 015\ L\text{/cu m}$$

$$\text{or} \quad = 1.5 \times 10^{-5}\ L\text{/cu m}$$

DISCUSSION AND REVIEW QUESTIONS

Chapter 4. RACKS, SCREENS, COMMINUTORS AND GRIT REMOVAL

DO NOT USE IBM ANSWER SHEET. Please write your answers in your notebook. The purpose of these questions is to indicate to you how well you understand the material in this chapter.

1. Why should coarse material (rocks, boards, metal) be removed at the plant entrance?
2. Why do you think the wastewater treatment and pollution control industry has a higher accident rate than most other industries reporting to the National Safety Council?
3. What are the advantages of comminutors over screens?
4. What precautions should be taken when cleaning a grit channel?
5. How can an operator regulate the velocity in a grit channel?
6. A stick travels 30 feet in 50 seconds in a grit channel. What is the flow velocity in the grit channel? Please show your calculations in a neat fashion so someone can help you if necessary.
7. Calculate the grit removed from a grit channel in cubic feet per million gallons if during a 24-hour period the average flow was 3 MGD and 4.5 cu ft of grit were removed.
8. What would you do if the screens or comminutor in your plant were overloaded or bypassed?
9. Why should an operator be given the opportunity to review the plans and specifications for the expansion of existing facilities or construction of a new wastewater treatment plant?

SUGGESTED ANSWERS

Chapter 4. RACKS, SCREENS, COMMINUTORS AND GRIT REMOVAL

Answers to questions on page 61.

4.0A True
4.0B True
4.0C True

Answers to questions on page 62.

4.1A (e) All of these.

4.1B Large pieces of material, such as rocks, boards, metal, and rags, are removed by racks and screens.

4.1C Coarse debris must be removed at the plant entrance to prevent damage to pumps, plugging of pipes, and filling of digesters.

Answers to questions on page 69.

4.2A (b), (c), and (d). Usually bar screens are very sturdy and will not collapse under the load from a blockage or an uncleaned screen.

4.2B Check to make sure that your footing will be secure by removing any slippery substances such as water and grease. Be certain there is adequate space to safely lift the screenings and a receptacle for the screenings (debris).

4.2C Visually identify what appears to be the cause of the problem, then shut off the machine if you must work on the equipment. Any moving equipment is hazardous, regardless of its speed.

4.3A Screenings may be disposed of by covering them with a minimum of six inches of earth or by incineration.

4.3B

$$\text{Quantity Removed, cu ft/MG} = \frac{\text{Volume Removed, cu ft/day}}{\text{Average Flows, MGD}}$$

$$= \frac{11 \text{ cu ft/day}}{4.4 \text{ MGD}}$$

$$= 2.5 \text{ cu ft/MG}$$

$$\begin{array}{r} 2.5 \\ 4.4\overline{)\,11.0} \\ 8\,8 \\ \hline 2\,2\,0 \\ 2\,2\,0 \\ \hline 0 \end{array}$$

Answers to questions on page 80.

4.4A Advantages of comminuting machines over screens include the elimination of screenings disposal, flies, and odor problems. A disadvantage is that plastic and wood may be rejected and must be removed manually.

4.4B Mechanical seals have replaced mercury seals in comminutors.

4.4C (d). Mercury must be handled with caution at all times.

4.4D Bar racks and screens remove debris from the wastewater while comminution units grind up debris and leave it in the wastewater.

Answers to questions on page 90.

4.5A (b) and (d). Grit is composed of heavy material that will settle in the grit chamber at proper flow velocities.

4.5B Grit must be removed to prevent wear in pumps, plugged lines, and the occupation of valuable space in digesters.

4.6A (a) Vary the number of channels in service in a multiple-channel installation.

(b) Use of proportional weirs.

(c) Lining sides with bricks or cinder blocks if velocity is too low. This could occur in a new plant.

You have the right idea if your answer includes possible adjustments of the cross-sectional area of the flow channel.

4.6B (a) Velocity = 0.5 ft/sec.

(b) Increase velocity to keep lighter organic solids moving.

4.6C Slipping or a back injury. Beware of dangerous gases when working in a covered grit channel. Also, there have been instances of gasoline or similar material leaking into the sewer and creating a potentially explosive hazard.

4.6D (a) Convert the flow of 2.75 MGD to cu ft/sec.

$$\begin{aligned}\text{Flow, cu ft/sec} &= \text{Flow, MGD} \times \frac{1.55\text{ cu ft/sec}}{\text{MGD}}\\ &= (2.75\text{ MGD})\frac{1.55\text{ cu ft/sec}}{\text{MGD}}\\ &= 4.3\text{ cu ft/sec}\end{aligned}$$

$$\begin{array}{r} 2.75\\ 1.55\\ \hline 13\,75\\ 137\,5\\ 275\\ \hline 4.2625\end{array}$$

(b) Convert depth of flow from 17 inches to feet.

$$\begin{aligned}\text{Depth, ft} &= \frac{17\text{ in}}{12\text{ in/ft}}\\ &= 1.4\text{ ft}\end{aligned}$$

$$\begin{array}{r} 1.4\\ 12\overline{)\,17.}\\ 12\\ \hline 5\,0\\ 4\,8\end{array}$$

(c) Calculate cross-sectional area of channel.

$$\begin{aligned}\text{Area, sq ft} &= \text{Depth, ft} \times \text{Width, ft}\\ &= 1.4\text{ ft} \times 3\text{ ft}\\ &= 4.2\text{ sq ft}\end{aligned}$$

(d) Calculate velocity.

$$\begin{aligned}\text{Average Velocity, ft/sec} &= \frac{\text{Flow, cu ft/sec}}{\text{Area, sq ft}}\\ &= \frac{4.26\text{ cu ft/sec}}{4.2\text{ sq ft}}\\ &= 1.01\text{, or 1 ft/sec}\end{aligned}$$

$$\begin{array}{r} 1.01\\ 4.2\overline{)\,4.26}\\ 4\,2\\ \hline 0\,60\\ 42\end{array}$$

4.7A The purpose of a cyclone grit separator is to separate grit from organic material and wastewater.

4.7B Safety hazards an operator may encounter when working around a cyclone grit separator include:

1. Electrical hazards,
2. Slowly-moving screw conveyors and other equipment,
3. Lifting heavy parts or materials, and
4. Slippery surfaces.

Answers to questions on page 90.

4.8A Grit is "washed" to remove organic material before disposal. If the organic matter is not removed, then odors could develop. If used as fill material, the fill could settle when the organics decompose.

4.8B Maintenance for a grit washer consists of:

1. Inspecting facility for corrosion damages;
2. Examining moving parts for wear; and
3. Lubricating and greasing facilities in accordance with plant O & M manual and manufacturer's instructions.

Answers to questions on page 92.

4.9A Grit removals should be recorded as cubic feet of grit per million gallons of flow.

Answer: 2 cu ft of grit/million gallons.

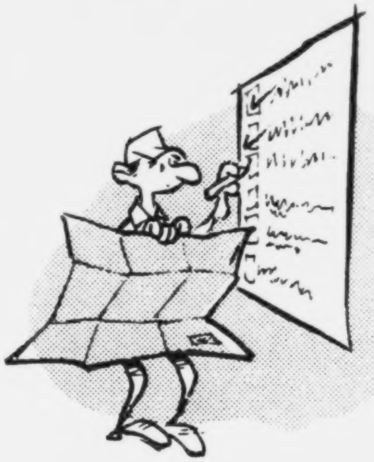
Answers to questions on page 93.

4.12A Problems created when screens or comminutors are overloaded or bypassed include:

1. Sticks and rags can foul the raw sludge pumps for the primary clarifiers,
2. Debris can plug the orifices in trickling filter distributors,
3. Debris can interfere with air diffusers in the aeration tanks of activated sludge plants,
4. Floating debris can appear in chlorine contact basin and the final effluent, and
5. Solids can plug return sludge pumps and flow meters in activated sludge plants.

4.13A When checking the plans and specifications for racks and screens, determine if there is:

1. Room for a rake when removing screenings;
2. Space so rake handle will not hit any buildings, overhead wires, light posts or overhead lights;
3. Some place to drain and store screenings;
4. A disposal site for the screenings;
5. Sufficient number of channels and capacity of racks and screens;
6. Provision to handle peak storm flows;
7. A sufficient number of standby units;
8. Hoist to remove screenings if necessary;
9. Dock facility for loading containers of screenings;
10. Adequate water under sufficient pressure for hosing down machinery and area; and
11. Sufficient spare parts.



OBJECTIVE TEST

Chapter 4. RACKS, SCREENS, COMMINUTORS AND GRIT REMOVAL

Please mark correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer.

1. You must always wash your hands before eating or smoking to prevent becoming infected with a water-borne disease.
   1. True
   2. False
2. Slipping and falling is one of the major safety hazards encountered by wastewater treatment plant operators.
   1. True
   2. False
3. Raw wastewater is another term for plant effluent.
   1. True
   2. False
4. Detritus is a common name for skimmings.
   1. True
   2. False
5. Septic wastewater looks black and smells like rotten eggs.
   1. True
   2. False
6. A sudden surge of septic wastewater into a treatment plant can cause a "shock load" on the treatment processes.
   1. True
   2. False
7. Manually cleaned screens are cleaned every eight hours.
   1. True
   2. False
8. Screenings are usually pumped to an anaerobic digester for treatment.
   1. True
   2. False
9. The velocity of wastewater flowing through a grit channel affects the effectiveness of grit removal.
   1. True
   2. False
10. Sludge and grit are both treated by the same processes.
    1. True
    2. False
11. Pretreatment may include
    1. Bar screens.
    2. Clarifiers.
    3. Detritus.
    4. Digesters.
    5. Grit channels.
12. Which of the following items may be found in a treatment plant influent?
    1. Cans
    2. Clothes
    3. Eggshells
    4. Rocks
    5. Toys
13. Grit is composed mostly of
    1. Floating wood and paper.
    2. Grease and scum.
    3. Plastics and rubber goods.
    4. Sand and eggshells.
    5. Sludge and organic materials.
14. A dead spot in a grit channel usually results in
    1. Deposits of grit that become compacted and hard.
    2. Deposits of grit that plug up the flow measuring device.
    3. Deposits of organic materials that become putrescible.
    4. Deposits of inorganic materials that become putrescible.
    5. No deposits of solids.
15. Safety hazards around mechanically cleaned bar screens and racks include
    1. Drowning.
    2. Electrical hazards.
    3. Pulling or lifting.
    4. Slippery surfaces.
    5. Traffic hazards.
16. What should be done *FIRST* when a problem develops in a mechanically cleaned screen?
    1. Attempt to fix the screen with the proper tools.
    2. Find someone to help in case you get into trouble.
    3. Reach in with your hand and fix the equipment.
    4. Read the plant O & M manual and determine how to correct the problem.
    5. Turn off the electrical power to the screen, tag and lock out.

17. The methods used to dispose of screenings ultimately include
    1. Burial.
    2. Dumping into a nearby river.
    3. Incineration.
    4. Selling for hog food.
    5. Using for fertilizer.

18. An aerated grit chamber will
    1. Freshen the plant effluent wastewater.
    2. Freshen the plant wastewater being treated.
    3. Increase BOD in wastewater being treated.
    4. Prevent clogging of flow measuring devices.
    5. Soften up the grit.

19. A stick travels 30 feet in 20 seconds in a grit channel. Estimate the flow velocity in the grit channel.
    1. 0.5 ft/sec
    2. 0.67 ft/sec
    3. 1.0 ft/sec
    4. 1.5 ft/sec
    5. 2.0 ft/sec

20. When starting or placing a comminutor in service, which of the following items would you perform?
    1. Adjust cutter blades if necessary.
    2. Check appearance and sound of comminutor.
    3. Check for proper positioning of inlet and outlet gates.
    4. Inspect for proper lubrication and oil levels.
    5. Look for frayed lifting cables on the screen.

21. What problems can develop in a wastewater treatment plant if screens or comminutors are overloaded or bypassed?
    1. Electrical controls can become jammed.
    2. Floating debris can appear in the chlorine contact basin.
    3. Floating debris can appear in the final effluent.
    4. No problems should develop with the downstream processes.
    5. Sticks and rags can foul the raw sludge pumps.

22. The rake on a mechanically cleaned bar screen appears OK, but will not move; however the motor is running. Possible causes of the problems include
    1. Broken chain.
    2. Broken shear pin.
    3. Limit switch is not working.
    4. Screen plugged.
    5. Rake mechanism jammed.

END OF OBJECTIVE TEST

CHAPTER 5

SEDIMENTATION AND FLOTATION

by

Elmer Herr

TABLE OF CONTENTS

Chapter 5. Sedimentation and Flotation

Page

OBJECTIVES 102
GLOSSARY 103

LESSON 1

5.0 Purpose of Sedimentation and Flotation 106
5.1 Operation and Maintenance 114
  5.10 Start-Up Procedure 114
  5.11 Daily Operation and Maintenance 115
  5.12 Shutdown Procedure 115
  5.13 Operational Strategy 115
  5.14 Abnormal Conditions 116
  5.15 Troubleshooting 117
    5.150 Sludge Collector Failure 118
    5.151 Sludge Pump Failure 118
    5.152 Toxic Waste Discharge 118
5.2 Sampling and Laboratory Analysis 119
  5.20 Need for Sampling and Analysis 119
  5.21 Sampling 119
  5.22 Calculation of Clarifier Efficiency 119
  5.23 Typical Clarifier Efficiencies 120
  5.24 Response to Poor Clarifier Performance 120
5.3 Sludge and Scum Pumping 121
5.4 General Maintenance 122
5.5 Safety 122

LESSON 2

5.6 Principles of Operation 124
  5.60 Types of Units 124
  5.61 Primary Clarifiers 124
  5.62 Secondary Clarifiers 128

5.620 Trickling Filter Clarifiers 128
5.621 Activated Sludge Clarifiers 128
5.7 Review of Plans and Specifications 132
5.70 Operation 132
5.71 Maintenance 134
5.72 Safety 134
5.8 Flotation Processes 134

LESSON 3

5.9 Combined Sedimentation-Digestion Unit 136
5.90 Purpose of Unit 136
5.91 How the Unit Works 136
5.92 Sampling and Analysis 138
5.93 Operation 138
5.930 Start-Up Procedures 138
5.931 Normal Operation 141
5.932 Abnormal Operation 142
5.933 Shutdown Procedures 142
5.934 Operational Strategy 142
5.94 Maintenance 142
5.95 Safety 142
5.96 Acknowledgment 142
5.10 Imhoff Tanks 143
5.11 Septic Tanks 144
5.12 Arithmetic Assignment 144
5.13 Additional Reading 144
5.14 Metric Calculations 144
5.140 Conversion Factors 144
5.141 Problem Solutions 144

OBJECTIVES

Chapter 5. SEDIMENTATION AND FLOTATION

Following completion of Chapter 5, you should be able to do the following:

1. Inspect new sedimentation and flotation equipment for proper installation and operation,
2. Place new facilities in service,
3. Schedule and conduct operation and maintenance duties,
4. Sample influent and effluent, interpret lab results, and make appropriate adjustments in treatment process (procedures for selecting sample location and analysis of samples are presented in Chapter 16),
5. Recognize factors that indicate a clarifier is not performing properly, identify the source of the problem, and take corrective action,
6. Determine when, how often and how much sludge should be pumped,
7. Conduct your duties in a safe fashion,
8. Explain the principles of the sedimentation and flotation processes,
9. Determine loadings on a clarifier,
10. Keep accurate and appropriate records on the operation of the process,
11. Develop an operating strategy for clarifiers, and
12. Review plans and specifications for clarifiers.

GLOSSARY

Chapter 5. SEDIMENTATION AND FLOTATION

AEROBIC BACTERIA
(AIR-O-bick back-TEAR-e-ah)
AEROBIC BACTERIA

Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobic bacteria.

ANAEROBIC BACTERIA
(AN-air-O-bick back-TEAR-e-ah)
ANAEROBIC BACTERIA

Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical components which contain oxygen, such as sulfate (SO_4).

BULKING (BULK-ing)
BULKING

Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.

COAGULANTS (ko-AGG-you-lents)
COAGULANTS

Chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COLLOIDS (KOL-loids)
COLLOIDS

Very small, finely divided solids (particles that do not dissolve) that remain dispersed in liquid for a long time due to their small size and electrical charge.

COMPOSITE (PROPORTIONAL)
SAMPLE (com-POZ-it)
COMPOSITE (PROPORTIONAL)
SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

DENSITY (DEN-sit-tee)
DENSITY

A measure of how heavy a substance (solid, liquid or gas) is for its size. Density is expressed in terms of weight per unit volume, that is, grams per cubic centimeter or pounds per cubic foot. The density of water (at 4°C or 39°F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot.

DETENTION TIME
DETENTION TIME

The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

EMULSION (e-MULL-shun)
EMULSION

A liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid held in suspension in the other.

FLIGHTS
FLIGHTS

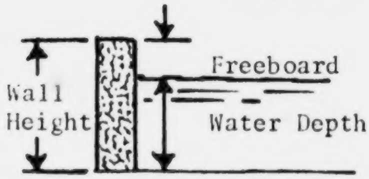
Scraper boards, made from redwood or other rot-resistant woods or plastic, used to collect and move settled sludge or floating scum.

FLOCCULATION (FLOCK-you-lay-shun)
FLOCCULATION

The gathering together of fine particles to form larger particles.

FREEBOARD FREEBOARD

The vertical distance from the normal water surface to the top of the confining wall.



GASIFICATION (GAS-i-fi-KAY-shun) GASIFICATION

The conversion of soluble and suspended organic materials into gas during anaerobic decomposition. In clarifiers the resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface.

HYDRAULIC LOADING HYDRAULIC LOADING

Hydraulic loading refers to the flows (MGD or cu m/day) to a treatment plant or treatment process. Detention times, surface loadings and weir overflow rates are directly influenced by the flows.

LAUNDERS (LAWN-ders) LAUNDERS

Sedimentation tank effluent troughs.

LINEAL (LIN-e-al) LINEAL

The length in one direction of a line. For example, a board 12 feet long has 12 lineal feet in its length.

MPN (EM-PEA-EN) MPN

MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume. Expressed as a density or population of organisms per 100 ml.

MASKING AGENTS MASKING AGENTS

Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.

MILLIMICRON (MILL-e-MY-cron) MILLIMICRON

One thousandth of a micron or a millionth of a millimeter.

MOLECULE (MOLL-uh-kule) MOLECULE

A molecule is the smallest portion of an element or compound that still retains or exhibits all the properties of the substance.

OSHA OSHA

The Williams-Steiger **O**ccupational **S**afety and **H**ealth **A**ct of 1970 (OSHA) is a law designed to protect the health and safety of industrial workers and treatment plant operators. It regulates the design, construction, operation and maintenance of industrial plants and wastewater treatment plants. The act does not apply directly to municipalities, *EXCEPT* in those states that have approved plans and have asserted jurisdiction under Section 18 of the OSHA Act. However, wastewater treatment plants have come under stricter regulation in all phases of activity as a result of OSHA standards. OSHA also refers to the federal and state agencies which administer the OSHA regulations.

PACKAGE TREATMENT PLANT PACKAGE TREATMENT PLANT

A small wastewater treatment plant often fabricated at the manufacturer's factory, hauled to the site, and installed as one facility. The package may be either a small primary or secondary wastewater treatment plant.

REPRESENTATIVE SAMPLE REPRESENTATIVE SAMPLE

A portion of material or water identical in content to that in the larger body of material or water being sampled.

RETENTION TIME RETENTION TIME

The time water, sludge or solids are retained or held in a clarifier or sedimentation tank. See DETENTION TIME.

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SLOUGHINGS (SLUFF-ings) SLOUGHINGS

Trickling-filter slimes that have been washed off the filter media. They are generally quite high in BOD and will lower effluent quality unless removed.

SLUDGE GASIFICATION

SLUDGE GASIFICATION

A process in which soluble and suspended organic matter are converted into gas by anaerobic decomposition. The resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface.

SPECIFIC GRAVITY

SPECIFIC GRAVITY

Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles usually have a specific gravity of 0.5 to 2.5.

SURFACE LOADING

SURFACE LOADING

Surface loading is calculated by dividing the flow into a sedimentation tank or a clarifier by the surface area of the unit.

$$\text{Surface Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

TOXIC (TOX-ick)

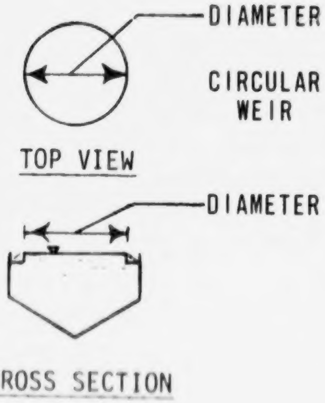
TOXIC

Poisonous. A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

WEIR DIAMETER (weer)

WEIR DIAMETER

Many circular clarifiers have a circular weir within the outside edge of the clarifier. All the water leaving the clarifier flows over this weir. The diameter of the weir is the length of a line from one edge of a weir to the opposite edge and passing through the center of the circle formed by the weir.



CHAPTER 5. SEDIMENTATION AND FLOTATION

(Lesson 1 of 3 Lessons)

NOTE: This chapter is divided into three lessons. The purpose is to divide the material into specific subject areas to make the information easier to study.

5.0 PURPOSE OF SEDIMENTATION AND FLOTATION

Raw or untreated wastewater contains materials which will either settle to the bottom or float to the water surface readily when the wastewater velocity is allowed to become very slow. Sewers are designed to keep the raw wastewater flowing rapidly to prevent solids from settling out in the collection-system lines. Grit channels (see Chapter 4) are designed to allow the wastewater to flow at a slightly slower rate than in the sewers so that heavy, inorganic grit will settle to the bottom where it can be removed. Settling tanks decrease the wastewater velocity far below the velocity in a collection sewer.

In most municipal wastewater treatment plants, the treatment unit which immediately follows the grit channel (see Figs. 5.1 and 5.2 for typical plant layout) is the *SEDIMENTATION AND FLOTATION UNIT*. This unit may be called a settling tank, sedimentation tank, or clarifier. The most common name is *PRIMARY CLARIFIER*, since it helps to clarify or clear up the wastewater.

A typical plant (Figs. 5.1 and 5.2) may have clarifiers located at two different points. The one which immediately follows the bar screen, comminutor or grit channel (some plants don't have all of these) is called the *PRIMARY CLARIFIER*, merely because it is the first clarifier in the plant. The other, which follows other types of treatment units, is called the *SECONDARY CLARIFIER* or the *FINAL CLARIFIER*. The two types of clarifiers operate almost exactly the same way. The reason for having a secondary clarifier is that other types of treatment following the primary clarifier convert more solids to the settleable form, and they have to be removed from the treated wastewater. Because of the need to remove these additional solids, the secondary clarifier is considered part of these other types of processes.

The main difference between primary and secondary clarifiers is in the density of the sludge handled. Primary sludges are usually denser than secondary sludges. Effluent from a secondary clarifier is normally clearer than primary effluent.

Solids which settle to the bottom of a clarifier are usually scraped to one end (in rectangular clarifiers) or to the middle (in circular clarifiers) into a sump. From the sump the solids are pumped to the sludge handling or sludge disposal system. Systems vary from plant to plant and include sludge digestion, vacuum filtration, incineration, land disposal, lagoons and burial. Figures 5.3, 5.4 and 5.5 show detailed sketches of rectangular and circular clarifiers. Tables 5.1 and 5.2 list the purposes of the parts of the clarifiers.

Disposal of skimmed solids varies from plant to plant. Skimmed solids may be buried with material cleaned off the bar screen, incinerated, or pumped to the digester. Even though pumping skimmed solids to a digester is not considered good practice because skimmings can cause operational problems in digesters, it is a common practice.

This chapter contains information on start up, daily operation, shut down and maintenance procedures; sampling and laboratory analyses; some problems to look out for; safety; and basic principles of sedimentation and flotation. You may wish to refer to Chapters 16 and 17 which contain details of laboratory analyses and mathematics for further information.

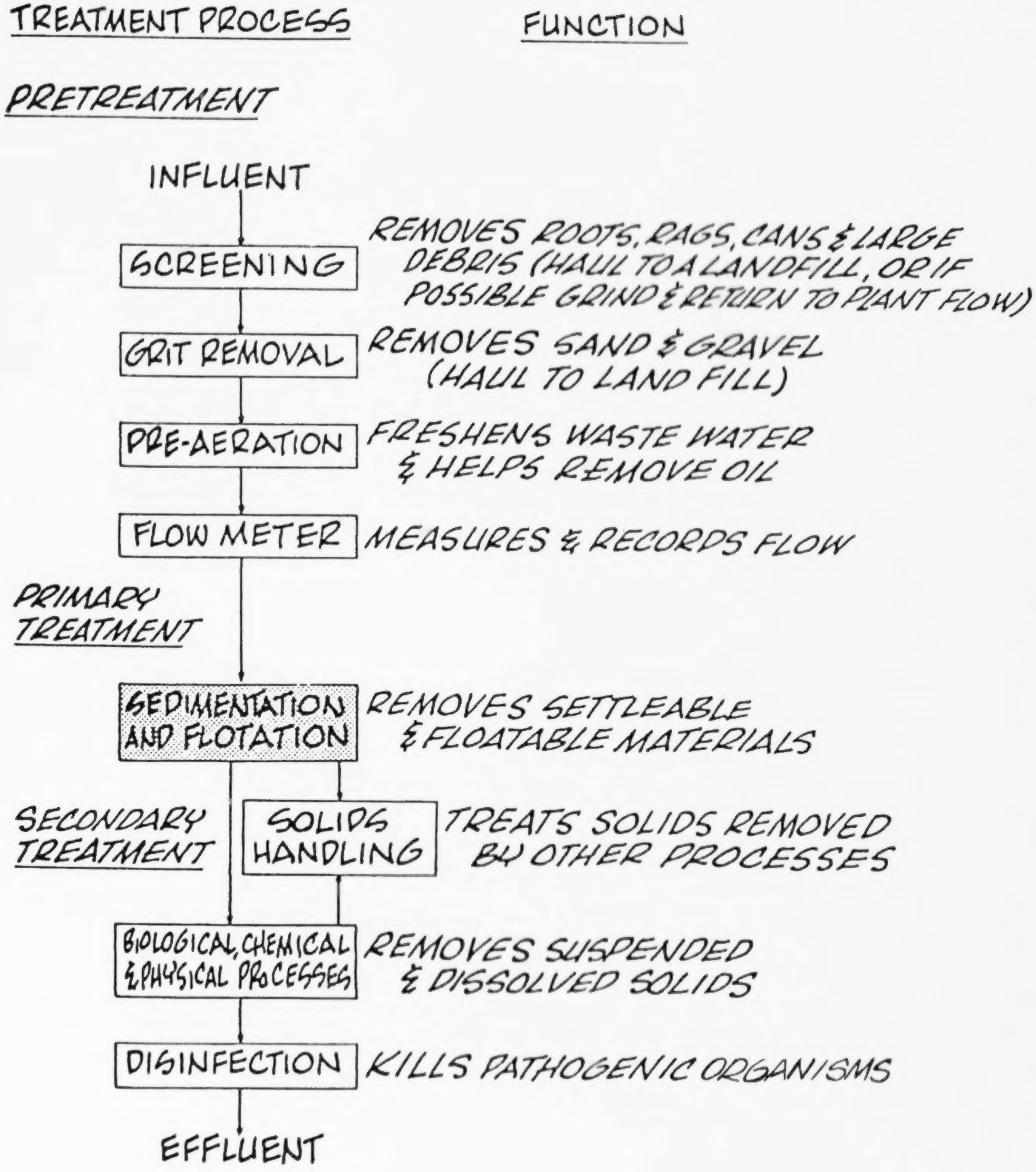

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
BIOLOGICAL, CHEMICAL & PHYSICAL PROCESSES
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
EFFLUENT

Fig. 5.1 Flow diagram of typical plant

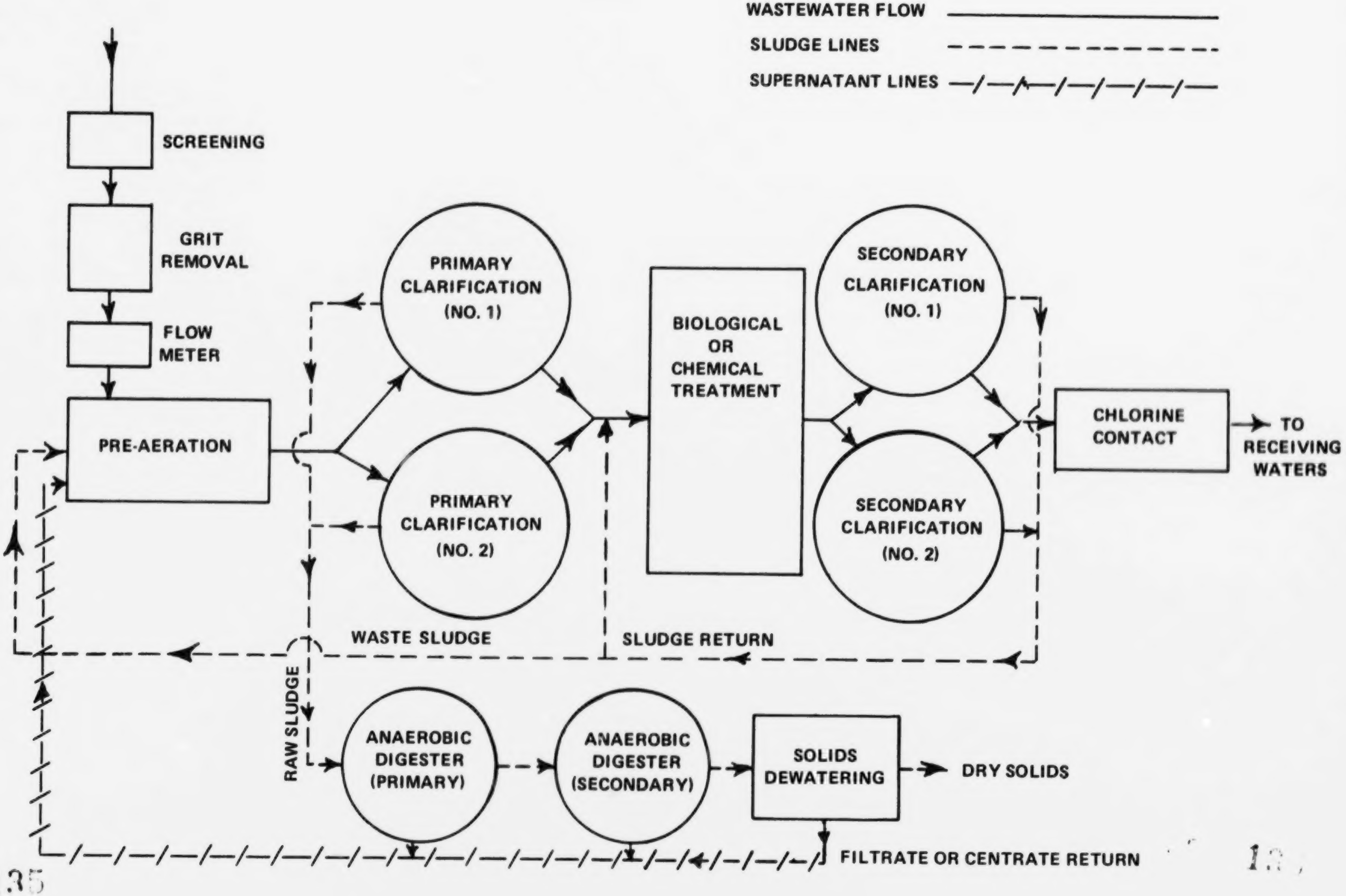

WASTEWATER FLOW
SLUDGE LINES
SUPERNATANT LINES
SCREENING
GRIT REMOVAL
FLOW METER
PRE-AERATION
PRIMARY CLARIFICATION (NO. 1)
PRIMARY CLARIFICATION (NO. 2)
BIOLOGICAL OR CHEMICAL TREATMENT
SECONDARY CLARIFICATION (NO. 1)
SECONDARY CLARIFICATION (NO. 2)
CHLORINE CONTACT
TO RECEIVING WATERS
WASTE SLUDGE
SLUDGE RETURN
RAW SLUDGE
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SOLIDS DEWATERING
DRY SOLIDS
FILTRATE OR CENTRATE RETURN

Fig. 5.2 Plan diagram of typical clarifiers in a wastewater treatment plant

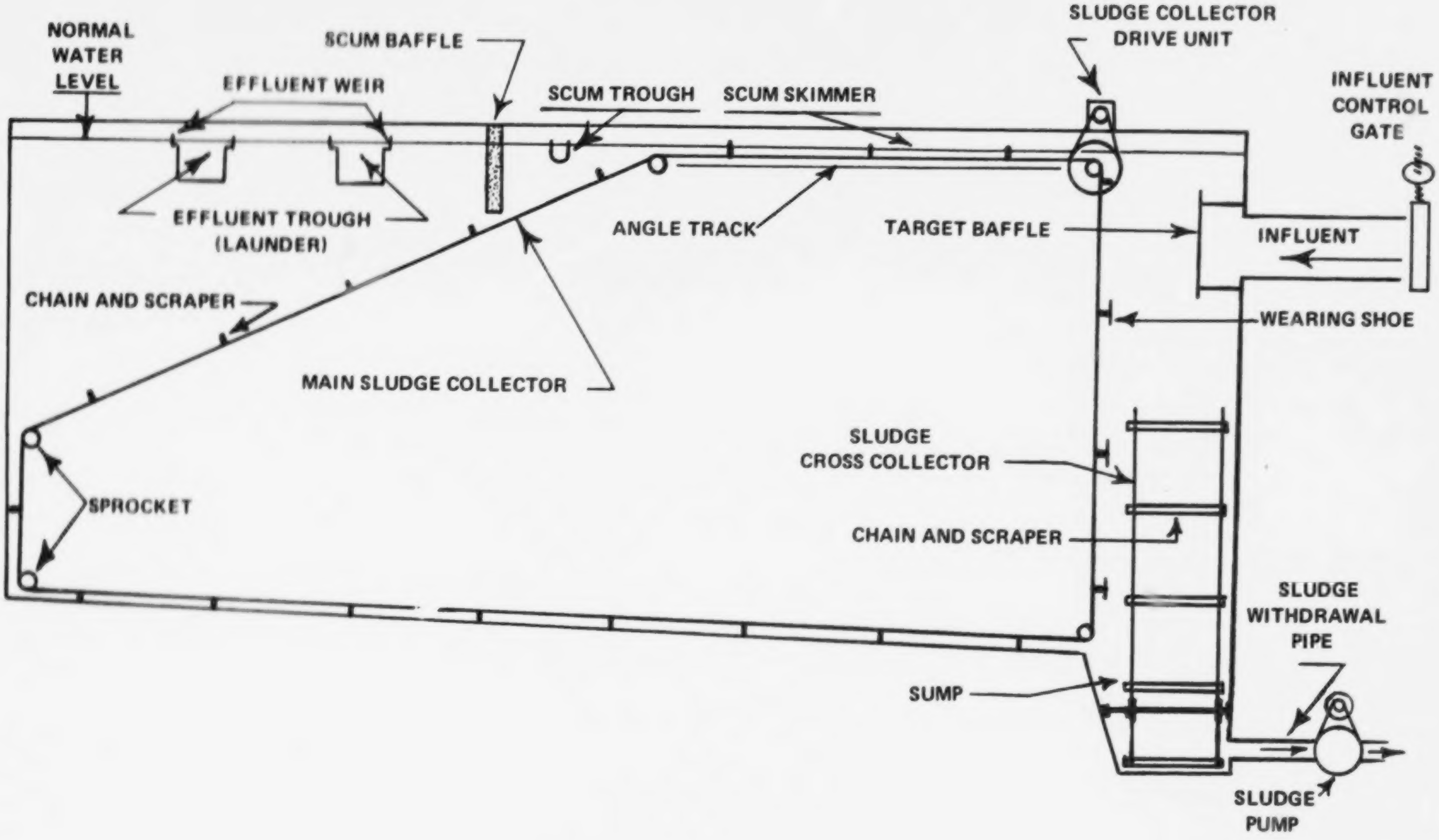

NORMAL WATER LEVEL
SCUM BAFFLE
EFFLUENT WEIR
SCUM TROUGH
SCUM SKIMMER
SLUDGE COLLECTOR DRIVE UNIT
INFLUENT CONTROL GATE
EFFLUENT TROUGH (LAUNDER)
ANGLE TRACK
TARGET BAFFLE
INFLUENT
CHAIN AND SCRAPER
WEARING SHOE
MAIN SLUDGE COLLECTOR
SLUDGE CROSS COLLECTOR
SPROCKET
CHAIN AND SCRAPER
SLUDGE WITHDRAWAL PIPE
SUMP
SLUDGE PUMP

Fig. 5.3 Side-view section of a rectangular sedimentation basin

137

138

TABLE 5.1 PURPOSE OF RECTANGULAR SEDIMENTATION BASIN AND PARTS

Part	Purpose
1. Influent Control Gate	Throttles or stops the flow to the sedimentation basin or clarifier.
2. Influent Channel or Pipe	Transports wastewater to the clarifier.
3. Target Baffle or Deflector Plate	Spreads the wastewater evenly across the width of the clarifier for even distribution and prevents short-circuiting.
4. Effluent Weir	Insures equal flow over all weirs. Designed for small surface elevation (water level) adjustments in the clarifier provided the plate is designed for vertical movement (up or down).
5. Effluent Trough (Launder)	Collects the settled wastewater flowing over the weirs and conveys it from the sedimentation basin.
6. Main Sludge Collector	Drags settled solids (sludge) to the sump. A continuous chain with cross pieces (flights or scrapers) attached.
7. Cross Collector	Drags sludge to deep end of sump for removal by pumping. Also prevents bridging of sludge in sump.
8. Sump	Receives settled sludge from the floor of the sedimentation basin. Stores sludge in sufficient quantity to avoid frequent (less than once per hour) removal by pumping, but of sufficient volume to maintain sludge thickness and to exclude water in the sedimentation basin from being pumped out during the pumping cycle.
9. Sludge Withdrawal Pump	Removes the sludge from the sump (pit).
10. Scum Skimmer or Collector	Skims or collects floating material from the surface of the wastewater and moves it to the scum trough.
11. Scum Trough	Receives the floating material from the scum skimmer for removal.
12. Scum Baffle	Extends above the water surface and prevents the floating material from reaching the effluent trough.
13. Sludge Collector Drive	Provides power which causes the main and cross collector units to move.
14. Sprocket	Supports chain, adjusts tension or forces the chain to move. A wheel with teeth around the outside that fit in the chain link.
15. Wearing Shoe	Prevents wear on the scraper cross pieces. Usually a piece of iron attached close to the outer ends of the scrapers.
16. Angle Track	Provides a track on which the main collector cross pieces ride.

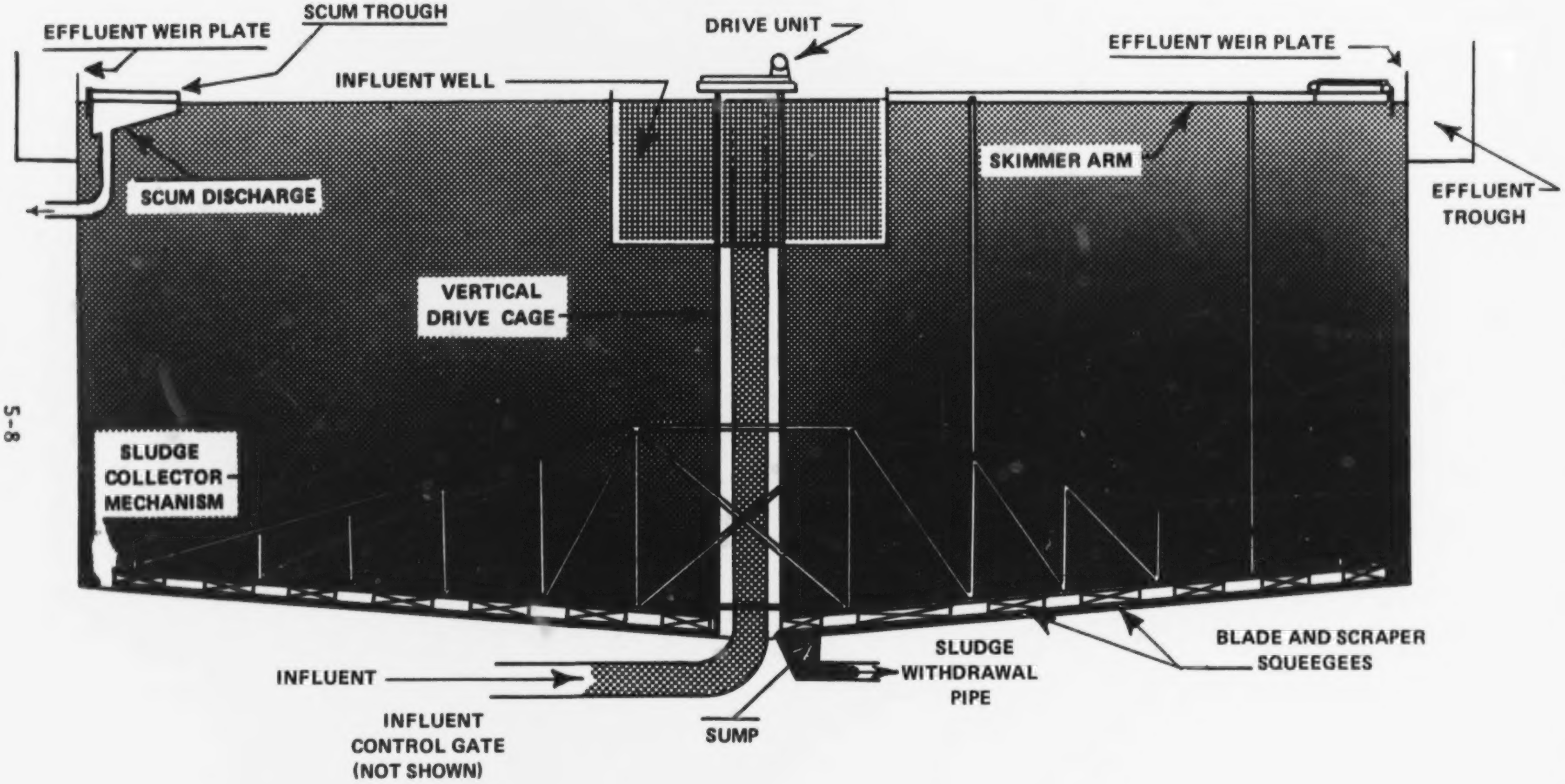

EFFLUENT WEIR PLATE
SCUM TROUGH
DRIVE UNIT
INFLUENT WELL
EFFLUENT WEIR PLATE
SKIMMER ARM
SCUM DISCHARGE
EFFLUENT TROUGH
VERTICAL DRIVE CAGE
SLUDGE COLLECTOR MECHANISM
BLADE AND SCRAPER SQUEEGEES
SLUDGE WITHDRAWAL PIPE
INFLUENT
INFLUENT CONTROL GATE (NOT SHOWN)
SUMP

Fig. 5.4 Side-view section of a circular clarifier with blades and scraper squeegees

TABLE 5.2 PURPOSE OF CIRCULAR CLARIFIER AND PARTS

Part	Purpose
1. Influent Control Gate	Throttles or stops the flow to the clarifier.
2. Influent Channel or Pipe	Transports wastewater to the clarifier.
3. Influent Well	Receives the flow from the influent pipe, reduces flow velocities and distributes flow evenly across the upper portion of the clarifier contents. A small circular compartment in the top center of the clarifier.
4. Effluent Weir	Insures equal flow over all weirs. Designed for small surface elevation (water level) adjustments in the clarifier, provided the plate is designed for vertical movement (up or down).
5. Effluent Trough (Launder)	Collects the settled wastewater flowing over the weirs and conveys it from the clarifier.
6. Scum Skimmer Arm	Skims or collects floating material from the surface of the wastewater and moves it to the scum trough.
7. Scum Trough	Receives the floating material scraped from the surface by the scum skimming arm.
8. Scum Pipe	Allows the collected scum to flow from the skimmer box to a scum tank or a pump.
9. Drive Unit	Causes the collector to rotate. A power unit which is connected to the vertical drive cage and which causes the collector to rotate.
10. Vertical Drive Cage	Transmits power from drive unit to the sludge collector mechanism.
11. Sludge Collector Mechanism	Drags settled solids across clarifier bottom to a sludge collection pit or sump. A mechanism which rotates around the bottom of the clarifier and consists of squeegee-type scrapers.
12. Blades and Scraper Squeegees	Scrape sludge from bottom of clarifier to sump.
13. Sump	Collects the sludge before withdrawal.
14. Sludge Withdrawal Pipe	Removes the sludge from the clarifier. Usually connected to a sludge pump.

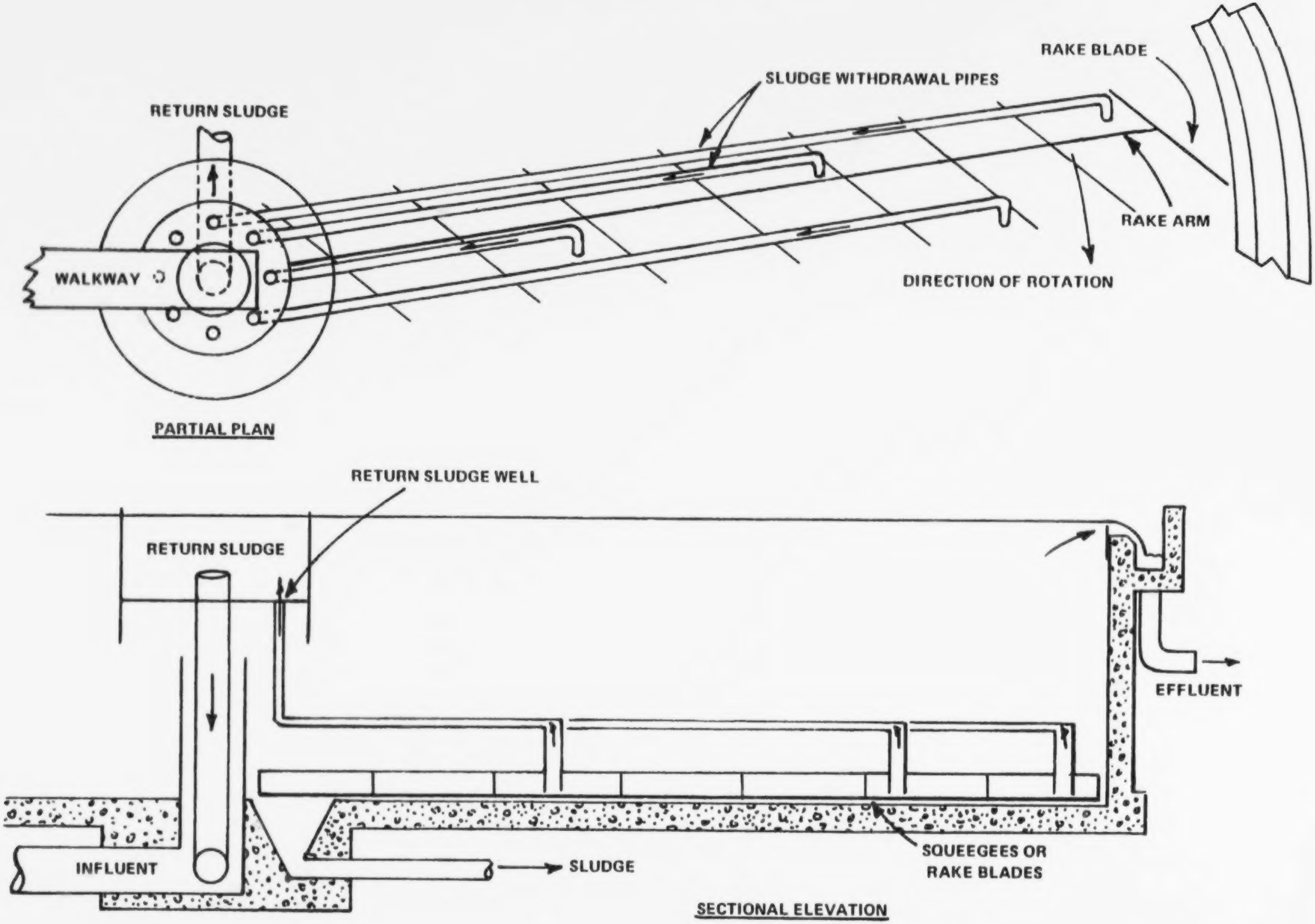

RAKE BLADE
SLUDGE WITHDRAWAL PIPES
RETURN SLUDGE
RAKE ARM
WALKWAY
DIRECTION OF ROTATION
PARTIAL PLAN
RETURN SLUDGE WELL
RETURN SLUDGE
EFFLUENT
INFLUENT
SLUDGE
SQUEEGEES OR
RAKE BLADES
SECTIONAL ELEVATION

Fig. 5.5 Side-view section of a circular clarifier with riser suction pipes

5.1 OPERATION AND MAINTENANCE

5.10 Start-Up Procedure

Before starting a new unit or one which has been out of service for cleaning or repair, inspect the tank carefully as outlined in this section. Now is a good time to become familiar with the "internal workings" of the clarifier because they are usually under water.

A. Circular Clarifiers

Check items:

1. Control gates for proper operation.
2. Clarifier tank for sand and debris.
3. Collector drive mechanism for lubrication, oil level, drive alignment, and complete assembly.
4. Gaskets, gears, drive chain sprockets and drive motor for proper installation and rotation.
5. Squeegee blades on the collector plows for proper distance from the floor of the tank.
6. All other mechanical items below water line for proper installation and operation.
7. Tank sumps or hoppers and return lines for debris and obstructions.
8. Tank structure for corrosion, cracks, and other indications of structural failure.

If everything checks out properly, turn on the mechanism. Let it make several revolutions while checking that the squeegee does not travel high or low, missing the bottom or scraping in some areas. The scraping action should control the entire area from the outside wall to the sludge hopper. Also be certain that the mechanism runs smoothly without jerks or jumps. Improper movement may be caused by problems with the drive unit, squeegees that have too much drag, or an uneven clarifier floor. If the unit is water lubricated, be sure sufficient water is in the tank to cover the center bearing.

If the unit is equipped with a stall alarm, test it to see if the mechanism will stop when overloaded. With the unit running, time the period it takes for the plows to make one complete revolution around the tank and *RECORD* the time for later reference.

Check and *RECORD* the amperage that the motor draws. Let the unit operate for several hours. If no problems develop, it should be okay.

Always be safety conscious, even during start-up.

1. If you are working down in the tank, wear a hard hat for protection from falling objects.
2. Keep hands away from moving equipment.
3. When working on equipment, be sure to red tag and use a lock-out device on start-stop switches and influent control gates to prevent equipment from starting unexpectedly and causing equipment damage and/or personal injury. If the lock-out device has a key, keep the key in your pocket.

B. Rectangular Clarifiers

The tank hoppers, channels, control gates, weirs, bearings, grease lines and drive alignment should be checked the same as for the circular clarifiers. The sludge collectors are different in rectangular clarifiers. Wooden crosspieces or *FLIGHTS*[1] are laid across the tank and each end is attached to an endless chain along both sides of the tank. The chains and crosspieces connected together as a unit are called the "collector mechanism." The collector chains are driven by a connecting shaft and sprockets that drag the crosspieces along rails imbedded in the floor of the tank and along each side just under the surface of the water.

Each wooden flight is equipped with metal wearing shoes to ride the rails. A metal wearing shoe usually is a flat metal plate attached to the end of the wooden flight to prevent excessive wear on the wood portion. Plastic wearing shoes may be used instead of metal ones.

Check to insure that the flights are straight across the tank, and that the chain on one side is not one or two links longer or shorter than the chain on the opposite side. If this occurs, the wooden flights will run at an angle across the tank. This either will cause sludge to pile higher on the trailing side or cause the flights to hang up with resultant severe damage to the flights.

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[1] *Flights. Scraper boards, made from redwood or other rot-resistant woods or plastic, used to collect and move settled sludge or floating scum.*

Caution should be exercised before starting the sludge collectors in an empty clarifier if they have not been operational for several weeks. The wearing shoes on the flights may have started rusting where they are sitting on the rails. A good practice is to lift each individual flight off the rail to be certain it is free and to apply a light grease or SAE 90 gear oil to the shoe and rail. If these precautions are not taken before the collector is turned on, the flight (wearing) shoes could stick to the rails and the whole collector system could be pulled down to the floor of the tank. Before the collectors are started in a new tank, each flight should be checked for a clearance of one to two inches (2.5 to 5 cm) between the wall and the end of the flight. If flights are too long, they may rub the tank wall and break the flight. Do not run a sludge collector very long in an empty tank if the lower shaft bearings of the collector mechanism depend on water rather than oil or grease for lubrication.

Safety precautions for the start-up of rectangular clarifiers are similar to those for circular clarifiers.

5.11 Daily Operation and Maintenance

During normal operations, you should schedule the following daily activities:

1. *INSPECTION*. Make several daily inspections with a stop, look, listen, and think routine.
2. *CLEANUP*. Using water under pressure, wash off accumulations of solid particles, grease, slime, and other material from walkways, handrails, and all other exposed parts of the structure and equipment.
3. *LUBRICATION*. Grease all moving equipment according to manufacturer's specifications and check oil levels in motors where appropriate.
4. *PREVENTIVE MAINTENANCE*. Follow manufacturer's specifications.
5. *FLIGHTS*. Examine bolts for looseness, corrosion, and excessive wear on those parts that can be inspected above the water line.
6. *CHAIN AND SPROCKET*. Check for wear because 0.05 inch (1.3 mm) wear on each of 240 link pins will cause about one foot (0.3 m) of extra slack.
7. *RECORD-KEEPING*. Write in your pocket notebook any unusual observations and transfer these notes to the plant record sheet (typical sheet is shown in the Appendix).
8. *SAMPLING AND LABORATORY ANALYSIS*. Details are in the next section (5.2).
9. *SLUDGE AND SCUM PUMPING*. See Section 5.3.

5.12 Shutdown Procedure

Annually during periods of low flow, each clarifier should be shut down for inspection, routine maintenance and any necessary repairs. Even though the clarifier and all equipment are working properly, an annual inspection helps to prevent serious problems and failures in the future when harmful consequences can result.

1. Divert the flow to other clarifiers and close the influent and effluent control gates of the clarifier being shut down.
2. Pump all remaining sludge to digester or to solids-handling system.
3. Dewater clarifier by draining remaining wastewater to headworks or pumping remaining wastewater to other clarifiers.
4. Hose down walls, floor and equipment inside clarifier while draining clarifier.
5. Inspect clarifier in accordance with Section 5.10, Start-Up Procedures (page 116).
6. Repair or replace all broken or defective equipment.
7. Repaint metal surfaces that have lost their protective coating or are showing signs of corrosion.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 146.

5.0A What is the main difference between the effluent from primary and secondary clarifiers?

5.0B What is the main difference between the sludge from primary and secondary clarifiers?

5.1A List the significant items to check before start-up of a circular clarifier.

5.1B What happens when the crosspieces in a rectangular clarifier are not straight across the tank?

5.1C What safety precautions should be taken during start-up of a clarifier?

5.13 Operational Strategy

The purpose of a sedimentation tank or clarifier is to remove settleable and floatable solids by sedimentation and flotation. The factor most often reported as influencing clarifier performance is the flow into the plant. Both the *SURFACE LOADING*[2] and *DETENTION TIME*[3] are directly related to flow (see Section 5.61, "Primary Clarifiers," page 126). In most plants the surface loading and detention time vary widely throughout the day due to the hourly changes in plant inflow resulting from the activities of the people and industries in the community. In spite of these great fluctuations, most clarifiers produce fairly consistent removals of BOD and suspended solids.

Most clarifiers that do not produce an acceptable effluent (see page 121) usually fail due to operator errors or equip-

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[2] *Surface Loading. Surface loading is calculated by dividing the flow into a sedimentation tank or a clarifier by the surface area of the unit.*

$$\text{Surface Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

[3] *Detention Time. The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.*

ment failures. The operator's job is very simple. Be sure that accumulated settled solids are removed from the bottom of the clarifier before *SEPTICITY*[4] and *GASIFICATION*[5] take place. Also be sure that surface floatables (oil and grease) are continuously or regularly skimmed and removed from the water surface to prevent floatables from reaching downstream secondary and disinfection processes.

Equipment or process failures caused by operator errors include:

1. Insufficient frequency or time for removing sludge;
2. Poor equipment maintenance and housekeeping; and
3. Insufficient knowledge of equipment and/or treatment process as related to:
   a. Laboratory analyses,
   b. Clarifier loadings,
      1) Flows, MGD
      2) Detention time, hr
      3) Surface area, gpd/sq ft
      4) Weir overflow, gpd/ft
      5) Solids, lbs solids/day/sq ft (secondary clarifiers)
      6) Solids balance, lbs/day in = lbs/day out
   c. Inability to recognize a mechanical-electrical problem, and
   d. Not restarting a drive mechanism that tripped out during a momentary power failure, such as one caused by a thunderstorm.

The best operational strategy for a clarifier is to develop and implement a good preventive maintenance program, to closely monitor operating conditions, and to respond to any lab results which indicate that problems are developing (see Section 5.24, "Response to Poor Clarifier Performance" on page 122). Any other clarifier problems usually result from abnormal conditions.

In large treatment plants with four or more clarifiers, plant performance may be improved by diverting flows to more or fewer clarifiers under certain circumstances. For example, during low flow periods from midnight until 6:00 am fewer clarifiers may be needed on the process flow line. To determine the number of clarifiers that should be on line, try not to allow detention times less than half an hour or longer than three hours to last longer than four to six hours without placing more or fewer clarifiers on line. Try to prevent detention times in primary clarifiers from becoming too long in order to keep the wastewater that is flowing to aerobic biological treatment processes fresh. To place an additional clarifier on line, or to take one off line, use the following procedures:

1. When placing a clarifier on line, open the inlet gate to the clarifier.
2. Operate the sludge collector, skimmer and pumps according to normal daily operating procedures.
3. When taking a clarifier off line, divert the wastewater being treated to other clarifiers by closing the clarifier inlet gate.
4. Collect the sludge on the bottom of the clarifier and pump the sludge from the hopper if it is thick enough to pump. Thickness of the sludge can be determined by the sound of the sludge pump, the use of thickness measuring sensors, or the observation of sludge through a sight glass.
5. The skimmer and sludge collector mechanism may be left on or turned off depending on the conditions of tank contents with regard to sludge left in the clarifier or scum on the water surface.

These procedures assume a clarifier being placed on line has been off line for less than two days. Also when a clarifier is taken off line, the assumption is made that the clarifier will be back on line within two days. Usually the number of secondary clarifiers on line remains constant on a daily or weekly basis; however, the same procedures apply if necessary. The number of secondary clarifiers on line may change with increases or decreases in seasonal flows or the condition of the solids in the secondary system. During extremely cold weather be careful that clarifiers which are not covered do not freeze when taken off the line. You may be better off leaving them on the line so they won't freeze during severe freezing conditions.

Operational strategies for secondary clarifiers following chemical and biological treatment processes are discussed in the following chapters related specifically to these processes. Also see Section 5.62, "Secondary Clarifiers," page 130.

5.14 Abnormal Conditions

Abnormal conditions influencing clarifier performance consist of:

1. *TOXIC*[6] wastes from industrial spills or dumps (also see Section 5.152, "Toxic Waste Discharge"),
2. Storm flows and hydraulic overloads, and
3. Septicity from collection system problems.

There is not much an operator can do in terms of clarifier operation to improve or maintain clarifier performance under these conditions. If any of these events occurs, corrective action should be taken. If a toxic waste dump is suspected or identified as the cause of a plant upset, immediate action should be taken to identify the source and prevent future dumps. A special step to minimize reduction in clarifier performance is the development and enforcement of a sewer-use ordinance. Other helpful activities include the installation of monitoring devices, instrumentation, control structures and chemical feed systems in order to provide the operator with the necessary tools to maintain clarifier performance.

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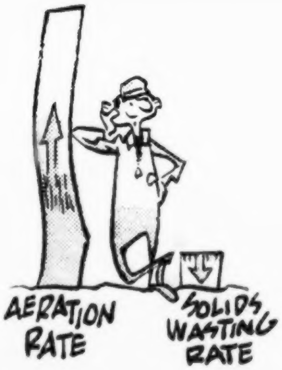
[4] Septicity (sep-TIS-it-tee). Septicity is the condition in which organic matter decomposes to form foul-smelling products associated with the absence of free oxygen. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

[5] Gasification (GAS-i-fi-KAY-shun). The conversion of soluble and suspended organic materials into gas during anaerobic decomposition. In clarifiers the resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface.

[6] Toxic (TOX-ick). Poisonous. A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

Shock loads from toxic wastes are best treated or controlled (after they are identified) by the addition of proper chemicals such as coagulants or chlorine at the plant headworks or at the preliminary treatment area. Some adjustments, such as increased recirculation rates with trickling filters to dilute the toxic wastes, may be successful in the secondary treatment processes.

In activated sludge plants, the impact of toxic wastes may be reduced if higher aeration rates will strip (drive out) the toxicants out of the mixed liquor. Usually this procedure is ineffective because the toxic waste has already passed through the plant before its impact is discovered. Reduction of the solids-wasting rate or stop wasting completely may help if some resistant bacteria have survived. If possible, change mode of operation to contact stabilization or step aeration, thereby exposing only a small portion of the organism population to the toxic waste. If all the bacteria have been destroyed or if the toxicant is bound in the sludge, get rid of the solids. Do not dispose of toxic solids in a digester. They may be disposed of in an approved sanitary landfill, provided you receive permission from the proper regulatory authorities.



If storm flow infiltration is a frequent problem, the sealing of sanitary sewers and/or the use of a flow equalization basin may improve the quality of clarifier effluent. There may not be much that can be done to prevent the development of septic wastewater in a collection system. Septic conditions can develop during hot weather when wastewater travel times in the collection system to the treatment plant become too long. Chemical treatment with chlorine or hydrogen peroxide added at a pump station may improve the condition of septic wastewater and protect structures from corrosion damages.

5.15 Troubleshooting

This section lists items that could fail in a circular or rectangular clarifier, how to detect the failure, the adverse effects of the failure, and how to remedy and prevent the failure. Also see Section 5.24, "Response to Poor Clarifier Performance," page 120.

5.150 Sludge Collector Failure

Detection of Failure

1. Sludge pump will pump very thin (watery) sludge indefinitely because the collector is not scraping the sludge to the pump suction.
2. Sludge is rising to the surface because it has been held in the tank too long and gasification has occurred.
3. Equipment stalls, stops, is noisy, or broken parts are observed.

Adverse Effects of Failure

1. Sludge builds up in clarifier. After equipment is in operation, the sludge may overload the digester. Watery sludge may wash organisms and alkalinity from digester.
2. Sludge may cause odors due to severe septic conditions.
3. Solids and soluble organics may carry over and overload the secondary treatment system.

Remedies

Circular tank

1. Restart equipment and inspect mechanism for rotation, stall alarm, and broken shear pin.

Rectangular tank

2. Inspect cross-collector drive, including shear pins and motor.
3. Inspect main collector drive, including shear pins, motor, drive chain, main chain and flights.

Both types of tanks

4. Take tank out of operation and place a standby clarifier in operation if available.
5. Identify failure and repair as soon as possible.
6. Reduce the flow if there is storage space in the collection system and make repairs immediately.

Preventive Measures

1. Check loadings and determine why mechanism stalled.
2. Conduct regular inspections.
3. Schedule and perform preventive maintenance.

5.151 Sludge Pump Failure

Detection of Failure

1. Pump does not pump. Failure may be due to burned out motor or electrical problem.
2. Sludge is rising to the surface because it has not been pumped from the tank and gasification has occurred.

Adverse Effects of Failure

1. Sludge builds up in clarifier. After equipment is in operation, the sludge may overload the digester.
2. Sludge may cause odors due to severe septic conditions.
3. Sludge build up may cause solid particles to pass over the weirs and upset other processes.
4. Disruption of regular solids feedings or loadings to digester.

Remedies

1. Inspect pump for failure by checking rotation, ball check valves and electrical circuits.
2. Examine check valves on pipes.
3. Identify failure and repair.
4. If available, operate standby pump until repairs are completed.

Preventive Measures

1. Conduct regular inspections.
2. Schedule and perform preventive maintenance.

5.152 Toxic Waste Discharge

Detection of Toxic Discharge

1. Color of incoming wastewater.
2. High or low pH.
3. Sludge *BULKING*.[7]
4. Odors.

Adverse Effects of Toxic Discharge

1. Organisms involved in wastewater and waste sludge processing or living in the receiving waters could be killed.
2. Possible violation of discharge and/or reuse requirements.

Remedies

1. If the sludge contains a high level of toxicity, one or more of several procedures may be necessary.
   a. *SLOWLY* pump sludge to digester.
   b. Pump sludge (dewatered if possible) to tank truck and dispose of sludge in an approved sanitary landfill.
   c. Neutralize toxic waste if possible.

Preventive Measures

1. Monitor plant influent. Testing of pH will reveal high or low levels.
2. Monitor industrial waste discharges.
3. Enforce sewer-use ordinances.

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[7] *Bulking (BULK-ing). Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.*

5.2 SAMPLING AND LABORATORY ANALYSIS

5.20 Need for Sampling and Analysis

Proper analysis of representative samples is the only conclusive method of measuring the efficiency of clarifiers. Tests may be conducted at the plant site where the sample is collected or in the laboratory. The tests performed depend on the downstream treatment processes.

Detailed procedures for performing control tests on primary treatment and sedimentation processes are outlined in Chapter 16, "Laboratory Procedures and Chemistry." The frequency of testing and the expected ranges will vary from plant to plant. Strength of the wastewater, freshness, characteristics of the water supply, weather, and industrial wastes will all serve to affect the "common" range of the various test results.

Tests	Frequency	Location	Common Range For Primary Clarifiers
1. Dissolved Oxygen (DO)	Daily	Effluent	0 - 2 mg/*L*
2. Settleable Solids	Daily	Influent Effluent	5 - 15 ml/*L* 0.3 - 5 ml/*L*
3. pH	Daily	Influent Effluent	6.5 - 8.0* 6.5 - 8.0*
4. Temperature	Daily	Influent	50 - 85°F* 10 - 30°C*
5. BOD	Weekly (Minimum)	Influent Effluent	150 - 400 mg/*L* 50 - 150 mg/*L*
6. Suspended Solids	Weekly (Minimum)	Influent Effluent	150 - 400 mg/*L*** 50 - 150 mg/*L***

Where discharge requirements permit primary treatment only, items 7 and 8 may be appropriate.

7. Chlorine Residual (if needed)	Daily	Plant Effluent	0.5 - 3.0 mg/*L* Depends on effluent requirement
8. Coliform Group Bacteria (if needed)	Weekly	Effluent	500,000 - 100,000,000 per 100 ml Depends on effluent requirement

* Depends on region, water supply and discharges to the collection system.

** Also may be recorded as packed volume from centrifuge test.

5.21 Sampling

Samples of the influent to the clarifier and the effluent from it will give you information on the clarifier efficiency as indicated by the test results listed in Section 5.20. As with all sampling, the purpose is to collect samples which represent the true nature of the wastewater or stream being sampled. The amount of solids, BOD, bacteria, and pH and temperature levels will probably vary throughout the day, week, and year. You must determine these variations in order to understand how well your clarifier is doing its job. Details on laboratory analysis and data recording are contained in Chapter 16, "Laboratory Procedures and Chemistry."

Test results obtained from collected samples may determine the number of clarifier units that should be in operation in order to obtain the best degree of treatment. Plants with more than one clarifier can have too many as well as not enough clarifiers in operation.

5.22 Calculation of Clarifier Efficiency

To calculate the efficiency of any wastewater treatment process, you need to collect samples of the influent and the effluent of the process, preferably *COMPOSITE SAMPLES*[8] for a 24-hour period. Next, measure the particular water quality indicators (for example, BOD, suspended solids) you are interested in and calculate the treatment efficiency. Calculations of treatment efficiency are for process control purposes. Your main concern must be the quality of the plant effluent, regardless of percent of wastes removed.

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[8] *Composite (Proportional) Sample (com-POZ-it). A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.*

EXAMPLE 1

The influent BOD to a primary clarifier is 200 mg/*L*, and the effluent BOD is 140 mg/*L*. What is the efficiency of the primary clarifier in removing BOD?

Formula

$$\text{Efficiency, \%} = \frac{(\text{In} - \text{Out})}{\text{In}}\,(100\%)$$

$$= \frac{(200\text{ mg}/L - 140\text{ mg}/L)}{200\text{ mg}/L}\,(100\%)$$

$$= \frac{(60\text{ mg}/L)}{200\text{ mg}/L}\,(100\%)$$

$$= (.30)\,(100\%)$$

$$= 30\%\text{ BOD Removal}$$

NOTE: The same formula is used for calculating the removal efficiency by a clarifier for all the water quality indicators (parameters) listed below in Section 5.23.

5.23 Typical Clarifier Efficiencies

Following is a list of some typical percentages for primary clarifier efficiencies:

Water Quality Indicator	Expected Removal Efficiency
Settleable solids	90% to 99%
Suspended solids	40% to 60%
Total solids	10% to 15%
Biochemical oxygen demand	20% to 50%
Bacteria	25% to 75%

pH generally will not be affected significantly by a clarifier. You can expect wastewater to have a pH of about 6.5 to 8.0, depending on the region, water supply and wastes discharged into the collection system.

Clarifier efficiencies are affected by many factors, including:

1. Types of solids in the wastewater, especially if there is a significant amount of industrial wastes.
2. Age (time in collection system) of wastewater when it reaches the plant. Older wastewater becomes stale or septic; solids do not settle properly because gas bubbles cling on the particles and tend to hold them in suspension.
3. Rate of wastewater flow as compared to design flow. This is called the "hydraulic loading."
4. Mechanical conditions and cleanliness of clarifier.
5. Proper sludge withdrawal. If sludge is allowed to remain in the tank, it tends to gasify and the entire sludge blanket (depth) may rise to water surface of clarifier.
6. Suspended solids, which are returned to the primary clarifiers from other treatment processes, may not settle completely. Sources of these solids include waste activated sludge, digester supernatant and sludge dewatering facilities (centrate from centrifuges and filtrate from filters).

5.24 Response to Poor Clarifier Performance

If laboratory analysis or visual inspection indicates that a clarifier is not performing properly, the source of the problem must be identified and corrective action taken. Listed below are clarifier problems with related items to be checked to identify the source of the problem. (Also see Section 5.15, "Troubleshooting.")

Problem	Check Items (pages 122 and 123)
1. Floating chunks of sludge	1, 2, 3, 4, 5
2. Large amounts of floating scum	2.3*, 2.4*, 2.5*
3. Loss of solids over effluent weirs	1, 2, 3, 4, 5, 2.7*, 2.8*
4. Low removal efficiencies	5
5. Low pH plus odors	1, 2, 3, 4, 5, 6
6. Deep sludge blanket, but pumping thin sludge	3, 2.1*, 2.2*, 2.3*, 2.6*
7. Sludge collector mechanism jerks or jumps	6
8. Sludge collector mechanism will not operate. Drive motor thermal overloads, or overload protective switches keep tripping.	6

* Check Item 2 is divided into two parts, (a) circular clarifier and (b) rectangular clarifier. If you have a floating scum problem (**Problem** 2 above), check under 2. COLLECTOR MECHANISM (page 123) either section (a) circular or (b) rectangular items 3, 4, and 5, depending on the type of clarifier in your plant.

CHECK ITEMS

1. SLUDGE PUMP[9]
   a. *PISTON PUMPS*
      1. Ball-check seating
      2. Shear pin
      3. Packing adjustment
      4. Drive belts
      5. High pressure switch
      6. Pumping time
   b. *POSITIVE DISPLACEMENT SCRU (SCREW) PUMPS*
      1. Pump gas bound
      2. Rotor plugged
      3. Drive belt
      4. Packing adjustment
      5. Pumping time
   c. *CENTRIFUGAL PUMPS*
      1. Pump gas bound
      2. Packing adjustment
      3. Impeller plugged
      4. Pumping time
   d. *AIR INJECTOR*
      1. Air supply
      2. Foot valves
      3. Slide valves
      4. Electrodes
      5. Pumping time

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[9] *For more information on pumps, see Chapter 15, "Maintenance."*

2. COLLECTOR MECHANISM
    a. *CIRCULAR CLARIFIER*
        1. Drive motor
        2. Overload switch
        3. Skimmer dump arm
            (a) operation
            (b) rubber squeegee
        4. Scum trough
        5. Scum box
    b. *RECTANGULAR CLARIFIER*
        1. Drive motor
        2. Clutch and drive gear
        3. Flights
        4. Scum trough
        5. Skimmer operation
        6. Cross collector
        7. Inlet line or slot
        8. Target baffle
3. PIPES AND SLUDGE SUMP

    Sometimes pipes or sumps may be cleaned by backflushing.
4. QUALITY OF SUPERNATANT RETURN FROM DIGESTER
5. INFLUENT
    a. *CHANGE IN COMPOSITION OR TEMPERATURE*
    b. *CHANGE IN FLOW RATE*

        An increase in flow rate can cause hydraulic overload. This can be determined by calculating the detention time, weir overflow rate, and surface loading rate (Section 5.61). If a tank is hydraulically underloaded, effluent could be recirculated back to the primary clarifier to reduce the length of detention time.
6. JERKING, JUMPING, OR STALLED COLLECTOR MECHANISM
    a. *SLUDGE BLANKET TOO DEEP*

        Pump out sludge if mechanism is all right.
    b. *DRIVE UNIT MAY HAVE BAD SPROCKET OR DEFECTIVE CHAIN LINK*
    c. *BROKEN FLIGHT, OR A ROCK OR STICK JAMMED BETWEEN FLIGHT OR SQUEEGEE BLADE AND FLOOR OF TANK*

    If items (b) or (c) occur, or mechanism won't operate properly, tank must be dewatered. Never attempt to back up or help pull a collector mechanism because severe equipment damage will result.

Your corrective action will depend on the source of the problem and the facilities available in your plant.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 147.

5.2A List five basic laboratory measurements used to determine clarifier efficiency.

5.2B About what percentage of settleable solids should you expect to be removed by your clarifier?

5.2C At what two points should samples be collected for measuring clarifier efficiency?

5.2D What is the suspended solids efficiency of a primary clarifier if the influent concentration is 300 mg/*L* and the effluent is 120 mg/*L*?

5.3 SLUDGE AND SCUM PUMPING

The particles which settle to the floor of the clarifier are called "sludge." The accumulated sludge should be removed frequently. This is accomplished by mechanical cleaning devices and pumps in most tanks. (See Figures 5.3, 5.4 and 5.5) Mechanically cleaned tanks need not be shut down for cleaning. *SEPTIC CONDITIONS* may develop rapidly in primary clarifiers if sludge is not removed at regular intervals. The proper interval is dependent on many conditions and may vary from thirty minutes to eight hours, and as much as twenty-four hours in a few instances. Experience will dictate the proper frequency of removal. Sludge septicity can be recognized when *SLUDGE GASIFICATION*[10] causes large clumps of sludge to float on the water surface. Septic sludge is generally very odorous and acid (has a low pH).

As thick a sludge as possible should be pumped from the clarifier sump with the least amount of water. The amount of sludge solids in the water affects the volume of sludge pumped and the digester operation. A good, thick primary sludge will contain from 4.0 to 8.0 percent dry solids as indicated by the Total Solids Test in the laboratory. Conditions which may affect sludge concentration are the specific gravity, size and shape of the particles, temperature of wastewater, and turbulence in the tank.

Withdrawal (pumping) rates should be slow in order to prevent pulling too much water with the sludge. While the sludge is being pumped, take samples frequently and examine them visually for excess water. If the samples show a "thin" sludge, it is time to stop pumping. Practice learning to recognize the differences between thin or concentrated sludges. There are several methods for determining "thick" or "thin" sludge without a laboratory analysis:

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[10] *Sludge Gasification. A process in which soluble and suspended organic matter are converted into gas by anaerobic decomposition. The resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface.*

1. Sound of the sludge pump. The sludge pump will usually have a different sound when the sludge is thick than when it is thin.
2. Pressure gage readings. Pressure will be higher on the discharge side of the pump when sludge is thick.
3. Sludge density gage readings.
4. Visual observation of a small quantity (gallon or less).
5. Watch sludge being pumped through a sight glass in the sludge line.

When you learn to use the indicators listed above, you should compare them frequently with lab tests. The laboratory Total Solids Test is the only accurate method for determining exact density. However, this analytical procedure is too slow for controlling a routine pumping operation. Many operators use the centrifuge test (see Chapter 16, "Laboratory Procedures and Chemistry") to obtain quick results.

Floating material (scum) may leave the clarifier in the effluent unless a method has been provided for holding it back. To collect scum, a baffle is generally provided at some location in the tank. Primary clarifiers often have a scum collection area where the scum is skimmed off by some mechanical method, usually a skimming arm or a paddle wheel. If mechanical methods are not provided, use hand tools such as a skimming dipper attached to a broom handle.

Frequently check the scum trough to be sure it is working properly. Clean the box with a brush and hot water. Scum may be disposed of by burning or burial.

See Chapter 15, Maintenance, Section 15.3 for details on how to unplug pipes and pumps.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 147.

5.3A How often should sludge be removed from a clarifier?

5.3B How can you tell when to stop pumping sludge?

5.3C How can floating material (scum) be kept from the clarifier effluent?

5.4 GENERAL MAINTENANCE

Following are some hints to help you keep your clarifiers operating properly:

1. Maintain a record-and-file system for future reference. This should contain sheets to write down a description and date for all repairs and regular maintenance activities such as lubrication. Other items to be kept in the file are operating instruction manuals; brochures; and names, addresses, and telephone numbers of manufacturer's representatives.
2. *ALWAYS* lubricate equipment at the intervals recommended by the manufacturer and use the *PROPER* lubricants (follow manufacturer's recommendations). Be sure that you do not over-lubricate.
3. Clean all equipment and structures regularly. Remove floating material and algae from inlet baffles and effluent weirs and launders. Keeping scum removal equipment clean and properly adjusted will help prevent odors.
4. Inspect and correct (if possible) all peculiar noises, leaks, pressure and vacuum gage irregularities, belts, electrical systems, and safety devices.
5. When a sedimentation tank must be drained for inspection or repairs, keep wooden flights moist by periodic sprinkling with a hose to prevent cracking and warping.
6. Keep the weirs level. This helps prevent short-circuiting which reduces the efficiency of the clarifier.

5.5 SAFETY

1. *GASES*

   Any enclosed area, such as a wet well for a pump, may have poisonous, asphyxiating, or explosive gases accumulated in it if ventilation is not proper. The most common of these gases are:

   a. Hydrogen Sulfide (H_2S). Causes a "rotten egg" odor. It readily combines with oxygen to form sulfuric acid which will dissolve concrete. If you breathe too much H_2S, it will cause an acid condition in the lungs and paralyze your respiratory center. In gaseous form, it can be flammable and explosive when mixed with the proper amount of air (oxygen).

   b. Chlorine (Cl_2). Very irritating to eyes, mouth, and nose. Causes death by suffocation (asphyxiation) and by formation of acid in the lungs. Chlorine is extremely dangerous (toxic). The proper type of breathing equipment (self-contained oxygen) should be readily available when working with chlorine.

   c. Carbon Dioxide (CO_2). Odorless, tasteless. This can cause asphyxiation by displacing oxygen in an enclosed, poorly ventilated area.

   d. Carbon Monoxide (CO). Colorless, odorless, nonirritating, flammable, explosive. Look out for carbon monoxide around gas engines or leaky gas systems in poorly ventilated places.

   e. Gasoline and other petroleum products. May cause fires or explosions, or displace oxygen and asphyxiate you.

   f. Methane (CH_4). Explosive, odorless, and may cause asphyxiation.

For a detailed discussion of the hazards and safety precautions when dangerous gases may be present, refer to Chapter 14, "Plant Safety and Good Housekeeping." The *NEW YORK MANUAL*, pages 174 and 175, Table 10, "Common Dangerous Gases Encountered in Sewers and at Sewage Treatment Plants," contains information on methods of testing for gases. Contact your local *OSHA*[11] office for approved procedures and equipment.

2. *FALLS*

Avoid falls by:

- a. Cleaning up oil and grease slicks on walkways *PROMPTLY.*
- b. *WALKING, NOT RUNNING,* when near open tanks.
- c. Avoid clutter. Pick up and store hoses, ropes, cables, tools, buckets, and lumber.
- d. Not sitting on, climbing through, or hanging over guardrails or handrails.
- e. Providing gratings, deck covers, or safety chains on or around openings to pits below floor level.

3. *DROWNING*

To prevent drowning:

- a. Put handrails and proper walkways by all open tanks.
- b. Cover open pits with gratings and deck plates.
- c. Have life preservers, life lines, or inner tubes handy to throw to anyone who may fall in. Appropriate equipment should be worn when necessary.
- d. Use the buddy system when working around or across a water surface. (Example: Skimming scum manually.)

4. *STRAINS AND OVEREXERTION*

Use proper tools or equipment:

- a. To move stuck or reluctant valves.
- b. To lift heavy objects.

ALWAYS
REMEMBER
SAFETY
FIRST

5. *ELECTRICAL SHOCK*

- a. Do not use water for cleaning electrical panels, electric motors, or other electrical equipment.
- b. Use rubber floor mats in front of electrical panels.
- c. Do not work on electrical equipment unless you are a qualified electrician and authorized to do so.

END OF LESSON
1 OF 3
LESSONS

on

SEDIMENTATION AND FLOTATION

Please answer the discussion and review questions before continuing with Lesson 2.

---

[11] *OSHA. The Williams-Steiger Occupational Safety and Health Act of 1970 (OSHA) is a law designed to protect the health and safety of industrial workers and treatment plant operators. It regulates the design, construction, operation and maintenance of industrial plants and wastewater treatment plants. The act does not apply directly to municipalities,* EXCEPT *in those states that have approved plans and have asserted jurisdiction under Section 18 of the OSHA Act. However, wastewater treatment plants have come under stricter regulation in all phases of activity as a result of OSHA standards. OSHA also refers to the federal and state agencies which administer the OSHA regulations.*

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 3 Lessons)

Chapter 5. SEDIMENTATION AND FLOTATION

At the end of each lesson in this chapter, you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in this section.

1. What is the function of a primary clarifier?
2. What items should be checked before starting a new clarifier or one which has been out of service for cleaning or repair?
3. Calculate the efficiency of a clarifier removing BOD if the influent BOD is 260 mg/*L* and the effluent is 155 mg/*L*. Show your work.
4. What would you do if the solids- and BOD-removal efficiencies of a primary clarifier suddenly dropped and the effluent appeared to contain more solids than usual?
5. What safety precautions should you take to avoid accidents when working around a treatment plant? List five that you consider most important.
6. How often should sludge be pumped from a primary clarifier?
7. What items should be inspected when a clarifier is taken out of service?
8. How would you dispose of sludge in a primary clarifier containing a toxic waste?

CHAPTER 5. SEDIMENTATION AND FLOTATION

(Lesson 2 of 3 Lessons)

5.6 PRINCIPLES OF OPERATION

5.60 Types of Units

Sedimentation and flotation units are designed to remove physically those solids which will settle easily to the bottom or float easily to the top. Sedimentation is usually the principal basis of design in such units and will be discussed in more detail in this section. Flotation of fats, oils, hair, and other light material also is very important to protect the aesthetics of receiving waters.

The sedimentation and flotation units commonly found are:

1. Primary clarifiers
2. Secondary clarifiers
3. Combined sedimentation - digestion units
4. Flotation units
5. Imhoff tanks

This section will describe each unit individually as it relates to another process or as a process by itself.

5.61 Primary Clarifiers

The most important function of the primary clarifier is to remove as much settleable and floatable material as possible. Removal of organic settleable solids is very important because they cause a high demand for oxygen (BOD) in receiving waters or subsequent biological treatment units in the treatment plant.

Many factors influence the design of clarifiers. Settling characteristics of suspended particles in water are probably the most important considerations. The design engineer must consider the speed at which particles will settle in order to determine the correct dimensions for the tank. Rapid movement of water (velocity) will hold most particles in suspension and carry them along until the velocity of water is slowed sufficiently for the particles to settle. The rate of downward travel (settling) of a particle is dependent on the weight of the particle in relation to the weight of an equal volume of water (*SPECIFIC GRAVITY*[12]), the particle size and shape, and the temperature of the liquid. Organic settleable solids are seldom more than 1- to 5-percent heavier than water; therefore, their settling rates are slow.

If the horizontal velocity of water is slowed to a rate of 1.0 to 2.0 feet of travel per minute (grit channel velocities were around 1 ft/sec), most particles with a specific gravity of 1.05 (5% more than water) will settle to the bottom of the container. Specific gravity of water is 1.000 at 4.0 degrees Celsius (formerly Centrigrade) or 39°F; it weighs 8.34 lbs per gallon. Wastewater solids with a specific gravity of 1.05 will weigh 8.76 lbs per gallon (1.05 times 8.34 lbs equals 8.76 lbs per gallon). The relationship of the particle settling rate to liquid velocity may be explained very simply by use of a sketch (Fig. 5.6).

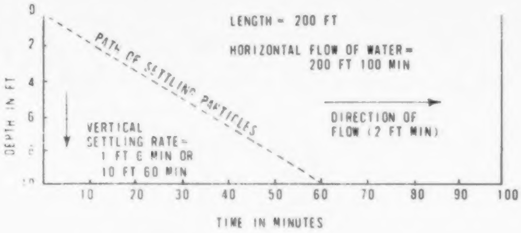


Fig. 5.6 Path of settling particle

Suppose the liquid velocity is horizontal at the rate of 2.0 feet per minute and the tank is 200 feet long. It will take 100 minutes (200 ft divided by 2.0 ft/min) to travel through the tank. If the particle, during its diagonal course of travel, settles vertically toward the bottom of the tank at a rate of 1.0 foot in 6 minutes, it will rest on the floor of the tank in 60 minutes if the tank is 10 feet deep. If the particle settles at the rate of 10 feet in 60 minutes, it should settle in the first 60 percent portion of the tank because the liquid surrounding it requires 100 minutes to flow through the tank.

---

[12] *Specific Gravity. Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles may have a specific gravity of 0.5 to 2.5. If the specific gravity of a particle is less than 1.0 it will tend to float. If it is greater than 1.0, it will tend to sink. Most organic sludges have a specific gravity between 1.01 and 1.05.*

There are many factors which will influence settling characteristics in a particular clarifier. A few of the more common ones are temperature, short circuits, detention time, weir overflow rate, surface loading rate, and solids loading. These factors are discussed in the following paragraphs.

1. *TEMPERATURE*. Water expands as temperature increases (above 4°C) or contracts as temperature decreases (down to 4°C). Below 4°C, the opposite is true. In general, as water temperature increases, the settling rate of particles increases; as temperature decreases, so does the settling rate. *MOLECULES*[13] of water react to temperature changes. They are closer together when liquid temperature is lower; thus, *DENSITY*[14] increases and water becomes heavier per given volume because there is more of it in the same space. As water becomes more dense, the density difference between water and solid particles becomes less; therefore the particles settle slower. This is illustrated in Fig. 5.7.

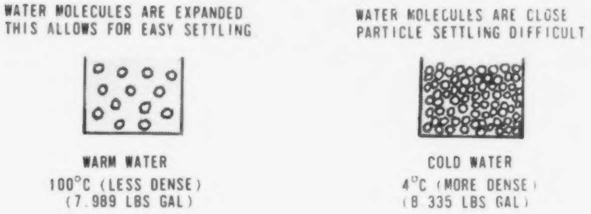
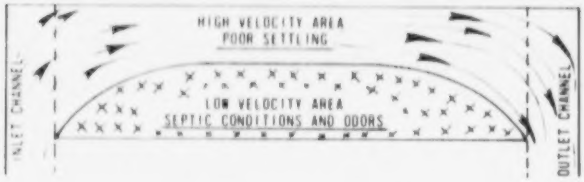

WATER MOLECULES ARE EXPANDED
THIS ALLOWS FOR EASY SETTLING
WATER MOLECULES ARE CLOSE
PARTICLE SETTLING DIFFICULT
WARM WATER
100°C (LESS DENSE)
(7.989 LBS GAL)
COLD WATER
4°C (MORE DENSE)
(8.335 LBS GAL)

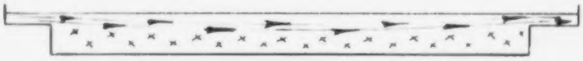
Fig. 5.7 Influence of temperature on settling

2. *SHORT CIRCUITS*. As wastewater enters the settling tank, it should be evenly dispersed across the entire cross-section of the tank and should flow at the same velocity in all areas toward the discharge end. When the velocity is greater in some sections than in others, serious short-circuiting may occur. The high velocity area may decrease the detention time in that area, and particles may be held in suspension and pass through the discharge end of the tank because they do not have time to settle out. On the other hand, if velocity is too low, undesirable septic conditions may occur. Short-circuiting may easily begin at the inlet end of the sedimentation tank (Fig. 5.8). This is usually prevented by the use of weir plates, baffles, port openings, and by proper design of the inlet channel.

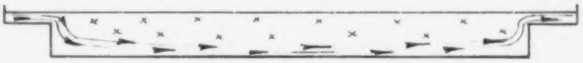
   Short-circuiting also may be caused by turbulence and stratification of density layers due to temperature or salinity. Temperature layers can cause short-circuiting when a warm influent flows across the top of cold water in a settling tank or when a cold influent flows under warm water in a settling tank.



Top View Looking Down



Side View - Warm Influent



Side View - Cold Influent

Fig. 5.8 Short circuiting

3. *DETENTION TIME*. Wastewater should remain in the clarifier long enough to allow sufficient settling time for solid particles. If the tank is too small for the quantity of flow and the settling rate of the particles, too many particles will be carried out the effluent of the clarifier. The relationship of *DETENTION TIME* to *SETTLING RATE* of the particles is important. Most engineers design settling tanks for about 2.0 to 3.0 hours of detention time. This is, of course, flexible and dependent on many circumstances.

Detention time can be calculated by use of two known factors:

1. Flow in gallons per day (gpd)
2. Tank dimensions or volume

EXAMPLE 2

The flow is 3.0 million gallons per day (MGD), or 3,000,000 gal/day. Tank dimensions are 60 feet long by 30 feet wide by 10 feet deep. What is the detention time?

FORMULAS:

$$\text{Detention Time, hrs} = \frac{\text{Tank Volume, cu ft} \times 7.5\ \text{gal/cu ft} \times 24\ \text{hr/day}}{\text{Flow, gal/day}}$$

$$\text{Tank Volume, cu ft} = \text{Length, ft} \times \text{Width, ft} \times \text{Depth, ft}$$

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[13] *Molecules (MOLL-uh-kules). A molecule is the smallest portion of an element or compound that still retains or exhibits all the properties of the substance.*

[14] *Density (DEN-sit-tee). A measure of how heavy a substance (solid, liquid or gas) is for its size. Density is expressed in terms of weight per unit volume, that is, grams per cubic centimeter or pounds per cubic foot. The density of water (at 4°C or 39°F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot. If one cubic centimeter of a substance (such as iron) weighs more than 1.0 gram (higher density), it will sink or settle out when put in water. If it weighs less (lower density, such as oil), it will rise to the top and float. Sludge density is normally expressed in gms/cc.*

CALCULATIONS:

$$\text{Tank Volume, cu ft} = \text{Length, ft} \times \text{Width, ft} \times \text{Depth, ft}^{15}$$

$$= 60\ \text{ft} \times 30\ \text{ft} \times 10\ \text{ft}$$

$$= 18{,}000\ \text{cu ft}$$

$$\text{Detention Time, hrs} = \frac{\text{Tank Volume, cu ft} \times 7.5\ \text{gal/cu ft} \times 24\ \text{hr/day}}{\text{Flow, gal/day}}$$

$$= \frac{18{,}000\ \text{cu ft} \times 7.5\ \text{gal/cu ft} \times 24\ \text{hr/day}}{3{,}000{,}000\ \text{gal/day}}$$

$$= \frac{3{,}240{,}000\ \text{gal-hr/day}}{3{,}000{,}000\ \text{gal/day}}$$

$$= 1.08\ \text{hours}$$

$$\begin{array}{r} 24 \\ \times\ 7.5 \\ \hline 120 \\ 168 \\ \hline 180.0 \end{array} \qquad \begin{array}{r} 18{,}000 \\ 180 \\ \hline 1{,}440{,}000 \\ 1{,}800{,}0 \\ \hline 3{,}240{,}000 \end{array}$$

EVALUATION. If detention time is only 1.08 hours and if laboratory tests indicate poor removal of solids, then additional tank capacity should be placed into operation (if available) in order to obtain additional detention time. You must realize that flows fluctuate considerably during the day and night and any calculated detention time is for a specific flow.

DISCUSSION. The formula given in this section allows you to calculate the *THEORETICAL* detention time. *ACTUAL* detention time is less than the detention time calculated using the formula and can be measured by the use of dyes, tracers, or floats.

4. *WEIR OVERFLOW RATE.* Wastewater leaves the clarifier by flowing over weirs and into effluent troughs (*LAUNDERS*)[16] or some type of weir arrangement. The number of *LINEAL*[17] feet of weir in relation to the flow is important to prevent short circuits or high velocity near the weir or launder which might pull settling solids into the effluent. The weir overflow rate is the number of gallons of wastewater that flow over one lineal foot of weir per day. Most designers recommend about 10,000 to 20,000 gallons per day per lineal foot of weir. Higher weir overflow rates have been used for materials with a high settling rate or for intermediate treatment. Secondary clarifiers and high effluent quality requirements generally need lower weir overflow rates than would be acceptable for primary clarifiers. The calculation for weir overflow rate requires two known factors:

   1. Flow in gpd
   2. Lineal feet of weir

EXAMPLE 3

The flow is 5.0 MGD in a circular tank with a 90-foot *WEIR DIAMETER*.[18] What is the weir overflow rate?

FORMULAS:

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow Rate, gpd}}{\text{Length of Weir, ft}}$$

$$\text{Length of Circular Weir} = 3.14 \times \text{Weir Diameter, ft}$$

CALCULATIONS:

$$\text{Length of Circular Weir, ft} = 3.14 \times (\text{Weir Diameter, ft})$$

$$= 3.14 \times 90\ \text{ft}$$

$$= 283\ \text{Lineal Feet of Weir}$$

$$\begin{array}{r} 3.14 \\ 90 \\ \hline 282.60 \end{array}$$

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow Rate, gpd}}{\text{Length of Weir, ft}}$$

$$= \frac{5{,}000{,}000\ \text{gal/day}}{283\ \text{ft}}$$

$$= 17{,}668\ \text{gpd/ft}$$

$$\begin{array}{r} 17{,}668 \\ 283\overline{)\,5{,}000{,}000} \\ 2\ 83 \\ \hline 2\ 170 \\ 1\ 981 \\ \hline 189\ 0 \\ 169\ 8 \\ \hline 19\ 20 \\ 16\ 98 \\ \hline 2\ 220 \\ 2\ 264 \end{array}$$

5. *SURFACE SETTLING RATE OR SURFACE LOADING RATE.* This rate is expressed in terms of gpd/sq ft of tank surface area. Some designers and operators have indicated that the *SURFACE LOADING RATE* has a direct relationship to the settleable-solids removal efficiency in the settling tank. The suggested loading rate varies from 300 to 1200 gpd/sq ft, depending on the nature of the solids and the treatment requirements. Low loading rates are frequently used in small plants in cold climates. In warm regions, low rates may cause excessive detention which could lead to septicity. The calculation for surface loading rate requires two known factors:

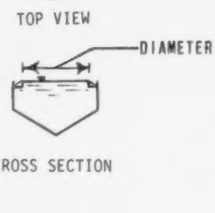
   1. Flow in gpd
   2. Square feet of liquid surface area

EXAMPLE 4

The flow into a clarifier is 4.0 MGD in a tank 90 feet long and 35 feet wide. What is the surface loading rate?

FORMULA:

$$\text{Surface Loading Rate, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Area, sq ft}}$$



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[15] *For a circular clarifier,* *Tank Volume, cu ft* $= 0.785 \times (\text{Diameter, ft})^2 \times$ *Depth, ft.*

[16] *Launders (LAWN-ders). Sedimentation tank effluent troughs. When the flow leaves a sedimentation unit, it usually flows into a trough after it leaves the tank. The top edge of the trough, over which wastewater flows as it enters the trough, is considered a weir.*

[17] *Lineal (LIN-e-al). The length in one direction of a line. For example, a board 12 feet long has 12 lineal feet in its length.*

[18] *Weir Diameter (weer). Many circular clarifiers have a circular weir within the outside edge of the clarifier. All the water leaving the clarifier flows over this weir. To find the length of this weir, the* WEIR DIAMETER *must be known. The diameter of the weir is the length of a line from one edge of a weir to the opposite edge and passing through the center of the circle formed by the weir.*

CALCULATIONS:

$$\text{Surface Area, sq ft} = \text{Length, ft} \times \text{Width, ft}^{19}$$

$$= 90 \text{ ft} \times 35 \text{ ft}$$

$$= 3150 \text{ sq ft}$$

$$\text{Surface Loading Rate, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Area, sq ft}}$$

$$= \frac{4{,}000{,}000 \text{ gpd}}{3150 \text{ sq ft}}$$

$$= 1270 \text{ gpd/sq ft}$$

6. *SOLIDS LOADING.* The term "solids loading" is used to indicate the amount of solids that can be removed daily by a clarifier for each square foot of clarifier liquid surface area. If the solids loading increases above design values, you can expect an increase in effluent solids. This concept can be applied to secondary clarifiers and gravity sludge-thickeners. Loading rates are expressed in pounds/day/sq ft and depend on the nature of the solids and treatment requirements. To calculate the solids loading requires three known factors:

   1. Flow in MGD;
   2. Suspended solids concentration in mg/*L*; and
   3. Liquid surface area in square feet.

EXAMPLE 5

A circular secondary clarifier with a diameter of 100 feet treats a flow of 4.5 MGD (3.5 MGD inflow and 1.0 MGD return sludge flow) with a mixed liquor suspended-solids concentration of 4200 mg/*L*. What is the solids loading in lbs/day/sq ft?

FORMULAS:

$$\text{Solids Applied, lbs/day} = \text{Flow, MGD} \times \text{Conc., mg/}L \times 8.34 \text{ lbs/gal}$$

$$\text{Solids Loading, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

CALCULATIONS:

$$\text{Solids Applied, lbs/day} = \text{Flow, MGD} \times \text{Conc., mg/}L \times 8.34 \text{ lbs/gal}^{20}$$

$$= 4.5 \text{ MGD} \times 4200 \text{ mg/}L \times 8.34 \text{ lbs/gal}$$

$$= 157{,}626 \text{ lbs/day}$$

$$\text{Surface Area, sq ft} = (0.785)(\text{Diameter, ft})^2$$

$$= (0.785)(100 \text{ ft})^2$$

$$= 7854 \text{ sq ft}$$

$$\text{Solids Loading, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

$$= \frac{157{,}620 \text{ lbs/day}}{7854 \text{ sq ft}}$$

$$= 20.0 \text{ lbs/day/sq ft}$$

TYPICAL SOLIDS LOADINGS:

Primary Clarifiers	Usually not a design consideration
Secondary Clarifiers (activated sludge)	12 to 30 lbs/day/sq ft
Dissolved-Air Flotation	5 to 40 lbs/day/sq ft
Sludge Thickening	5 to 20 lbs/day/sq ft

DETENTION TIME, WEIR OVERFLOW RATE, SURFACE LOADING RATE and *SOLIDS LOADING* are four mathematical methods of checking the performance of existing facilities against the design values. However, laboratory analysis of samples is the only reliable method of measuring clarifier efficiency. *IF LABORATORY RESULTS INDICATE A POORLY OPERATING CLARIFIER, THE MATHEMATICAL METHODS MAY HELP YOU TO IDENTIFY THE PROBLEM.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 149.

5.6A What is "short-circuiting" in a clarifier?

5.6B Why is "short-circuiting" undesirable?

5.6C How can "short-circuiting" be corrected?

5.6D A circular clarifier has a diameter of 80 feet and an average depth of 10 feet. The flow of wastewater is 4.0 MGD and the suspended-solids concentration is 190 mg/*L*. Calculate the following:

   1. Detention Time, in hours
   2. Weir Overflow Rate, in gpd/ft
   3. Surface Loading Rate, in gpd/sq ft

5.6E A circular clarifier has a diameter of 80 feet and an average depth of 10 feet. The clarifier treats 4.0 MGD from the plant inflow plus 1.2 MGD of return sludge flow. The mixed liquor suspended solids concentration is 2700 mg/*L*. Calculate the solids loading in lbs/day/sq ft.

---

[19] *For a circular clarifier,*
Surface Area, sq ft = 0.785 × (Diameter, ft)^2

[20] *The units of this formula can be proved by remembering that 1 liter equals or weighs one million milligrams.*

$$\frac{mg}{L} = \frac{mg}{1{,}000{,}000\ mg} = \frac{mg}{M\ mg}$$

Therefore,

$$\text{Flow, MGD} \times \text{Conc., mg/}L \times 8.34 \text{ lb/gal} = \frac{M\ gal}{day} \times \frac{mg\ SS}{M\ mg} \times \frac{lb}{gal} = \frac{lb\ SS}{day}$$

5.62 Secondary Clarifiers

Secondary clarifiers usually are located after a biological process in the flow pattern of a treatment plant. (See Fig. 5.2). The most common biological processes are the *ACTIVATED SLUDGE PROCESS*[21] and the *TRICKLING FILTER*.[22]

In some plants a chemical process may be used instead of a biological process, but the latter is far more common for municipal treatment plants.

5.620 *Trickling Filter Clarifiers*

A secondary clarifier is used after a trickling filter to settle out *SLOUGHINGS*[23] from the filter media. Filter sloughings are a product of biological action in the filter; the material is generally quite high in BOD and will lower the effluent quality unless it is removed. A detailed description of trickling filters can be found in Chapter 6.

Secondary tanks following trickling filters may be either circular or rectangular and have sludge-collector mechanisms similar to primary clarifiers. Clarifier detention times are about the same as for primary clarifiers, but the surface loading and weir overflow rates are generally lower due to the less dense characteristics of secondary sludges. The following are ranges of loading rates for secondary clarifiers used after biological filters:

Detention Time - 2.0 to 3.0 hours
Surface Loading - 800 to 1200 gpd/sq ft
Weir Overflow - 5,000 to 15,000 gpd/lineal ft

The amount of solids settling out in a secondary clarifier following a trickling filter will be very irregular due to a number of varying conditions in the biological treatment process. In general, you can expect to pump about 30 to 40 percent as much more sludge from the secondary clarifier as from the primary; thus total sludge pumping to the digester will increase by that amount. These figures indicate how the trickling filter "creates" settleable solids which were not present in the raw wastewater in settleable form.

The sludge in the secondary settling tank will usually have characteristics and appearance completely different than the sludge collected in a primary settling tank. This sludge will usually be much darker in color, but should not be grey or black. Sludge will turn black if it is allowed to stay in the secondary clarifier too long. If this happens, then the sludge pumping rate should be increased or the time of pumping lengthened or made more frequent. These sludges generally require frequent pumping. Pumps used to pump trickling filter sludges from secondary clarifiers are similar to raw sludge pumps and may be piston, progressive cavity or centrifugal-type pumps.

The particle sizes may be very irregular with generally good (rapid) settling characteristics. The sludge may appear to be a fluffy, humus-type material and usually will have little or no odor if sludge removal occurs at regular intervals. Disposal of sludge collected in the final settling tanks depends on the particular plant design and the characteristics of the sludge. Sometimes disposal is accomplished by transferring the sludge to a primary settling tank to be settled with primary sludge. Other times it is transferred directly to the digestion system.

5.621 *Activated Sludge Clarifiers*

Secondary clarifier tanks which follow the activated sludge process are designed to handle large volumes of sludge. They are more conservative in design because the sludge tends to be less dense. The following are ranges of loading rates for secondary clarifiers used after aeration tanks in the activated sludge process:

Detention Time - 2.0 to 3.0 hours
Surface Loading - 300 to 1200 gpd/sq ft
Weir Overflow - 5,000 to 15,000 gpd/lineal ft
Solids Loading - 24 to 30 lbs/day/sq ft

Their purpose is identical, except that the particles to be settled are received from the aeration tank rather than the trickling filter. Most secondary sedimentation tanks used with the activated sludge process are equipped with mechanisms capable of quickly removing the sludge due to the importance of rapidly returning sludge to the aeration tank. The sludge volume in the secondary tank will be greater from the activated sludge process than from the trickling filter process.

Sludge-removal mechanisms in secondary tanks have tended to differ from most primary clarifier mechanisms, especially those in circular clarifiers. These secondary circular clarifiers are designed for continuous sludge removal by *HYDROSTATIC SYSTEMS*,[24] with the activated sludge being pumped back to the aeration tanks by large capacity pumps. These pumps usually are of the centrifugal type with variable-speed controls or are of the large air-lift type.

Figures 5.9, 5.10, and 5.11 illustrate three variations of sludge-removal mechanisms for secondary clarifiers used in the activated sludge process. These mechanisms are designed to remove the settled activated sludge as rapidly as possible, thus reducing the sludge- *RETENTION TIME*[25] in the clarifiers. Several of these mechanisms have valves or adjustable rings to control the return sludge rates from the different collection points in the clarifier mechanism.

Flows may be regulated from each pipe removing activated sludge from the clarifier in order to control the activated sludge process. The reason for the ability to regulate each pipe is that different activated sludge densities will develop different settling patterns in a particular clarifier. For example, an activated

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[21] *Activated Sludge Process (ACK-ta-VATE-ed sluj). A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.*

[22] *Trickling Filter. A treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water being treated.*

[23] *Sloughings (SLUFF-ings). Trickling-filter slimes that have been washed off the filter media. They are generally quite high in BOD and will lower effluent quality unless removed.*

[24] *Hydrostatic Systems. In a hydrostatic sludge removal system, the surface of the water in the clarifier is higher than the surface of the water in the sludge well or hopper. This difference in pressure head forces sludge from the bottom of the clarifier to flow through pipes to the sludge well or hopper.*

[25] *Retention Time. The time water, sludge or solids are retained or held in a clarifier or sedimentation tank. See DETENTION TIME.*

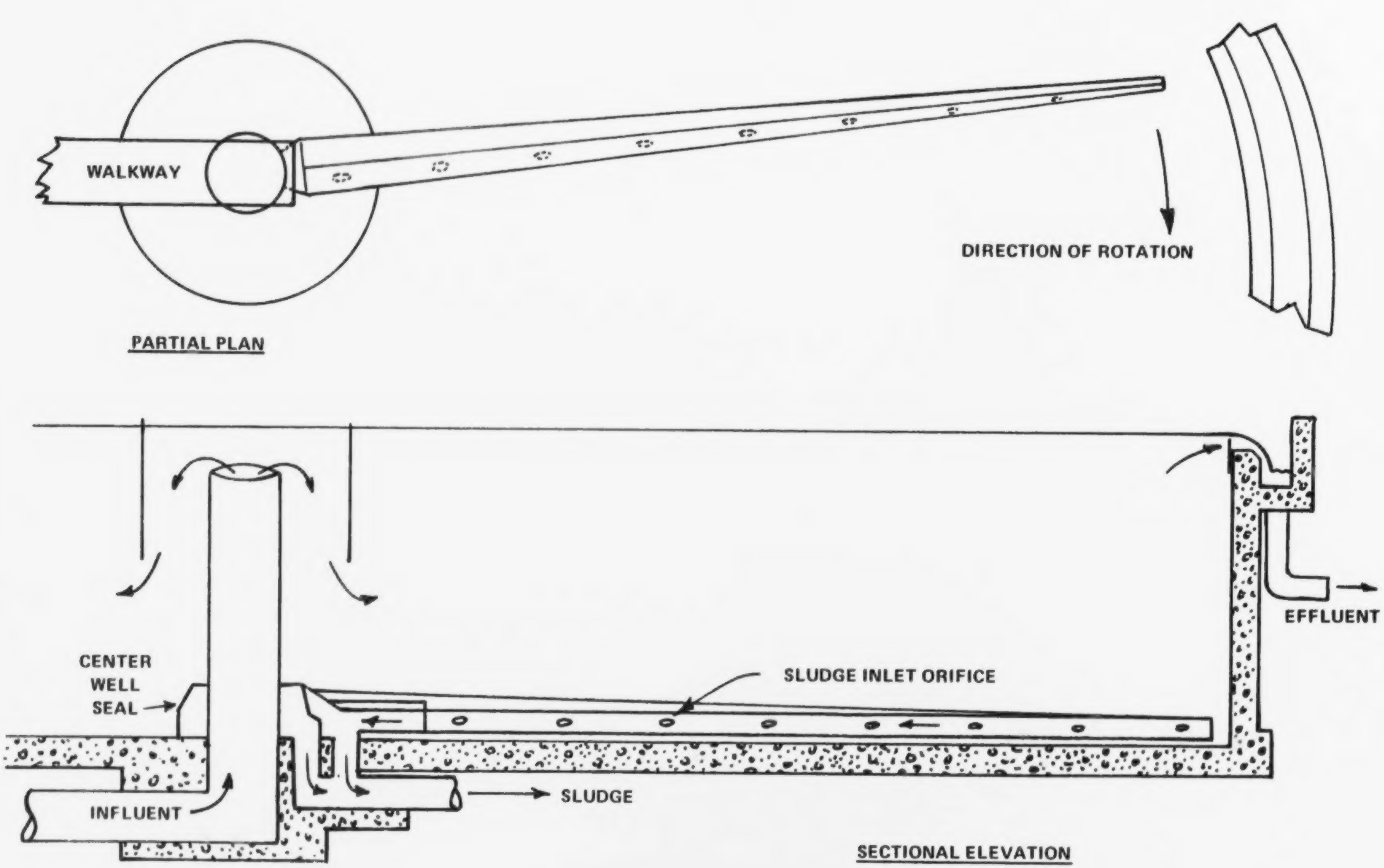
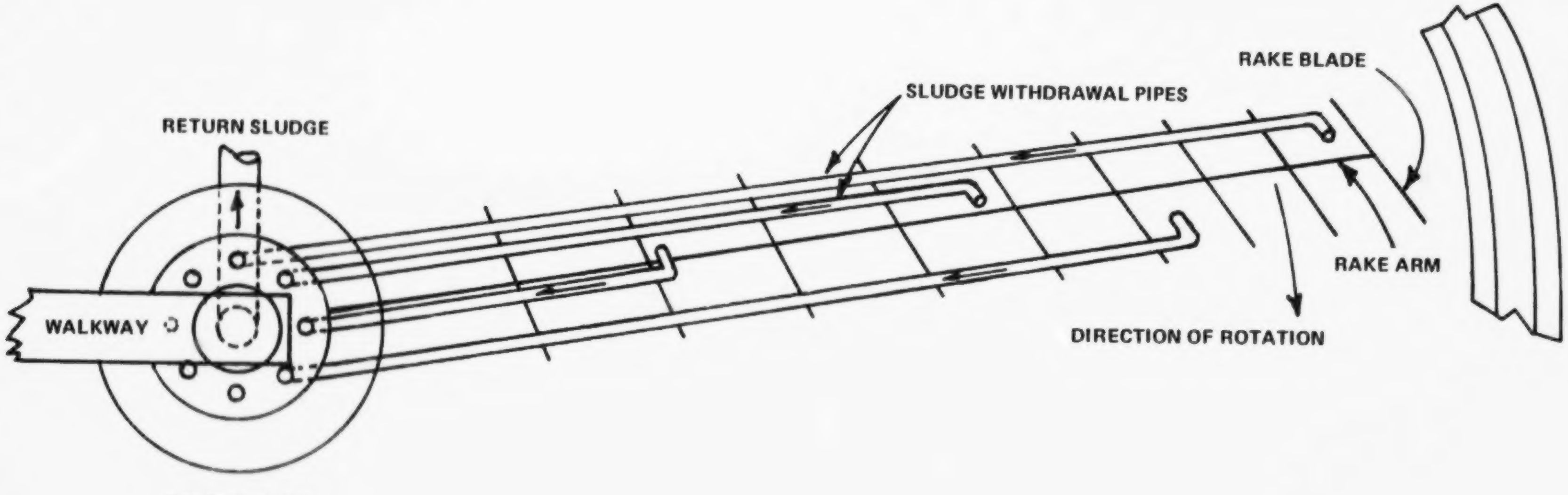
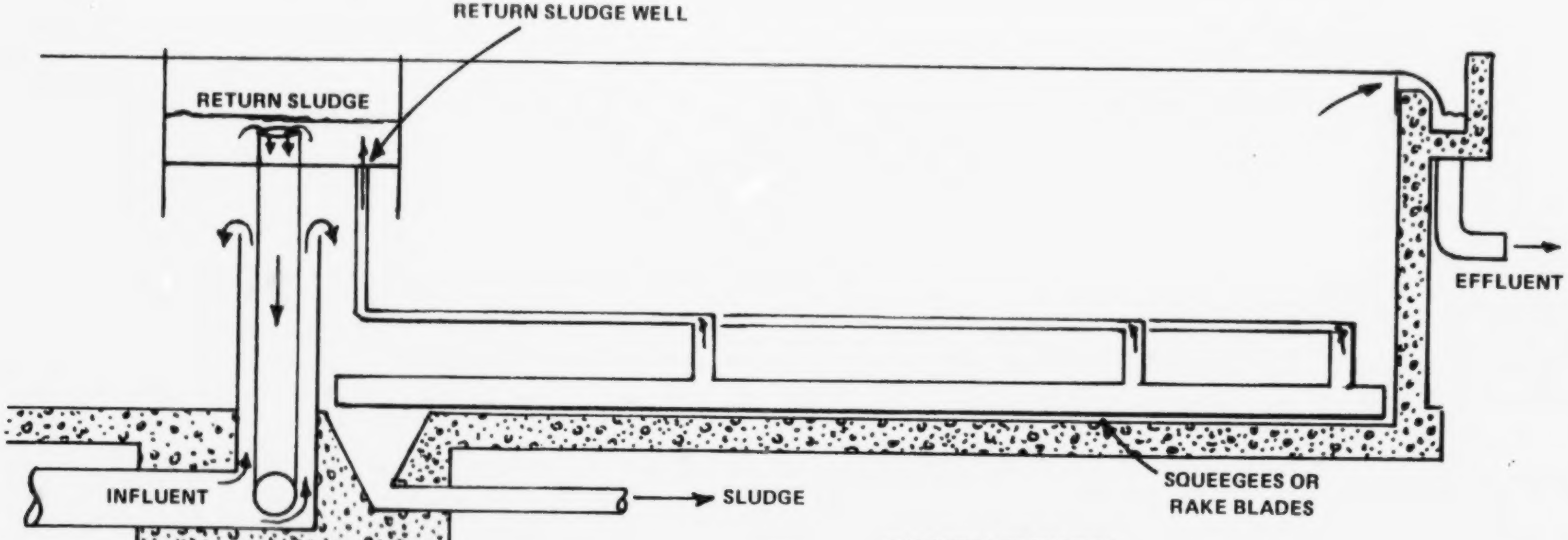

WALKWAY
DIRECTION OF ROTATION
PARTIAL PLAN
CENTER WELL SEAL
SLUDGE INLET ORIFICE
EFFLUENT
INFLUENT
SLUDGE
SECTIONAL ELEVATION

Fig. 5.9 Secondary clarifier sludge-removal mechanism
(Link Belt)


RAKE BLADE
SLUDGE WITHDRAWAL PIPES
RETURN SLUDGE
RAKE ARM
WALKWAY
DIRECTION OF ROTATION

PARTIAL PLAN


RETURN SLUDGE WELL
RETURN SLUDGE
EFFLUENT
INFLUENT
SLUDGE
SQUEEGEES OR RAKE BLADES

SECTIONAL ELEVATION

Fig. 5.10 Secondary clarifier sludge-removal mechanism

(Dorr Oliver)

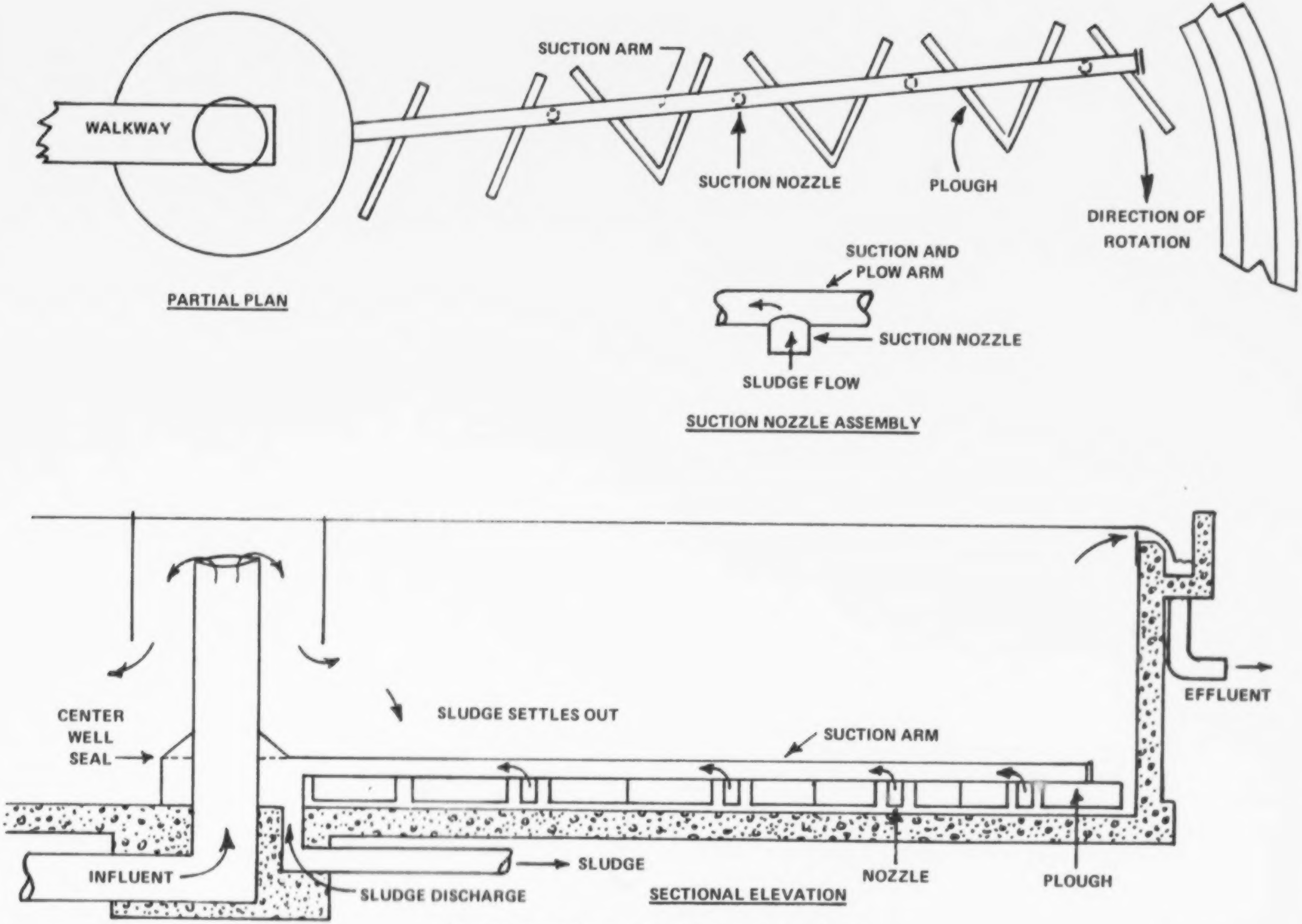

SUCTION ARM
WALKWAY
SUCTION NOZZLE
PLOUGH
DIRECTION OF ROTATION
PARTIAL PLAN
SUCTION AND PLOW ARM
SUCTION NOZZLE
SLUDGE FLOW
SUCTION NOZZLE ASSEMBLY
EFFLUENT
SLUDGE SETTLES OUT
CENTER WELL SEAL
SUCTION ARM
INFLUENT
SLUDGE
SLUDGE DISCHARGE
SECTIONAL ELEVATION
NOZZLE
PLOUGH

Fig. 5.11 Secondary clarifier sludge-removal mechanism

(Walker Process)

sludge with an *SVI*[26] of 100 will develop a bell pattern sludge blanket with most of the activated sludge solids settling near the tank inlet, thus requiring most of the sludge to be removed from the center or inner quarter of the tank floor area (Fig. 5.12).

If the activated sludge degrades to an SVI of 500, then the solids-settling curve takes on the shape of a bowl (Fig. 5.13). Under this condition the sludge gathers at the outside of the clarifier and requires higher return flow rates. Unfortunately the outside sludge return nozzles or pipes must handle a much larger clarifier bottom area than the inside pipes or nozzles. Regardless of the sludge condition, the operator must adjust return flow rates to remove solids from the tank areas where the activated sludge is settling by reducing the return sludge flows from areas where the activated sludge is not settling.

Under normal operating conditions, return sludge rates may range from 10 to 50 percent of the plant inflow. During times when the activated sludge process is upset, return sludge rates of 100 percent may be desirable in order to maintain sufficient activated sludge solids in the system. Under these conditions you must be careful that the return sludge rate does not become too high. During high return rates, the resulting turbulence in the tank can upset the sludge blanket.

Wasting of excess activated sludge from the system should be to some liquid-solids separation process other than the primary clarifier. In many plants, excess or waste activated sludge is processed by separate gravity or flotation sludge thickeners in order to concentrate the sludges to 3.0 to 4.5 percent solids before pumping the solids to the digester or dewatering system for disposal. Waste activated sludge pumped to the primary clarifiers in large plants usually develops into a solids buildup problem in the plant. This buildup consists of a cycle of ever increasing amounts of activated sludge being wasted to the primary clarifier which produces more raw sludge. When additional volumes of raw sludge are pumped to the digester, more supernatant carrying digester solids is returned to the headworks for treatment. These solids produce greater volumes of activated sludge and the cycle continues. This solids buildup creates a solids handling problem and deterioration of the effluent until one of these sources of solids is removed from the cycle to solve the problem.

Of all the different types of clarifiers that an operator must regulate, secondary clarifiers in the activated sludge process are the most critical and require the most attention from the operator. To help the operator regulate clarifier operation, aids have been developed which consist of instrumentation capable of monitoring:

1. Levels of sludge blanket in clarifier,
2. Concentration of suspended solids in clarifier effluent,
3. Control and pacing of return sludge flows,
4. Level of turbidity in clarifier effluent,
5. Concentration of dissolved oxygen (DO) in clarifier effluent, and
6. Level of pH.

Laboratory tests should be conducted to measure all of the above items and to provide a check on the accuracy of the instrumentation. Other tests that should be conducted on the clarifier effluent include biochemical oxygen demand (BOD) and ammonia nitrogen (NH_3-N) measurements.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 147.

5.6F Why are secondary clarifiers needed in secondary treatment plants?

5.6G What usually is done with the sludge that settles out in secondary clarifiers?

5.7 REVIEW OF PLANS AND SPECIFICATIONS

Plans and specifications should be reviewed by operators so they can:

1. Become familiar with a proposed plant,
2. Learn what will be constructed, and
3. Offer suggestions on how the plant can be designed for easier and more effective operation and maintenance.

When reviewing plans and specifications, carefully study those areas influencing how the plant will be operated and maintained. Also look carefully for potential safety hazards.

5.70 Operation

1. Control gates must be suitably located in order to isolate each clarifier.
2. Baffles, weirs or skirts should be capable of controlling clarifier inlet velocities.
3. Collector mechanisms and drive units must have protective devices such as shear pins, clutches, stall alarms, and on-off switches. Be sure that clarifiers with suction-type mechanisms for removing sludge have provisions for sludge removal from the center of the clarifier.
4. Surface skimmer for scum removal.
5. Scum box should be located with consideration given to direction of prevailing winds and to removal of any accumulation of floatables on the water surface.
6. Hose bibs (high-pressure water faucets) conveniently located with respect to scum boxes, launders, weirs and clarifier center columns for easy washdown.
7. Sampling equipment should be easily accessible.
8. Clarifier flow and level controllers (if installed) must be properly located for operational purposes.
9. Grease or scum weirs must be at proper depth for scum control and removal of floating material from water surface.

---

[26] *SVI. Sludge Volume Index. This is a test used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared with its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.*

$$SVI = \frac{\text{Wet Settled Sludge, ml}}{\text{Dried Sludge Solids, mg}} \times 1000$$

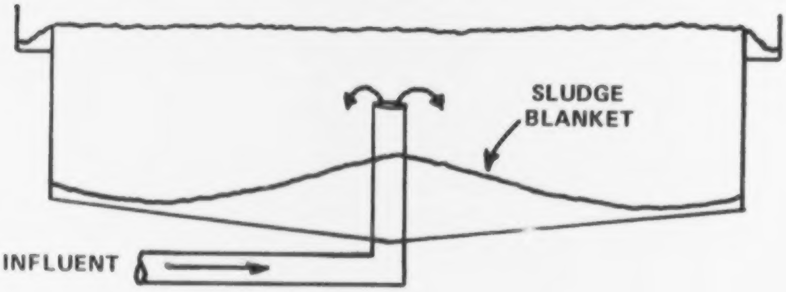

SLUDGE BLANKET
INFLUENT

Fig. 5.12 Activated sludge settling near center of clarifier
(bell-shaped pattern)

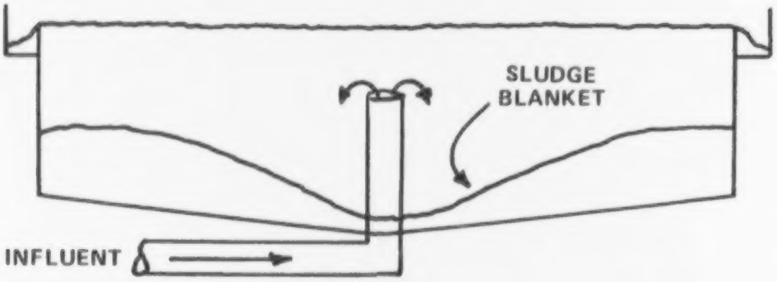

SLUDGE BLANKET
INFLUENT

Fig. 5.13 Activated sludge settling near outer edge of clarifier
(bowl-shaped pattern)

5.71 Maintenance

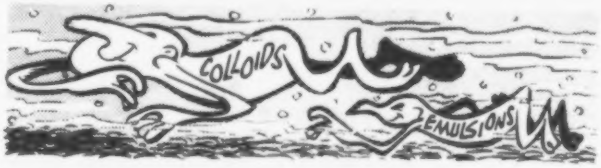
1. Drive mechanisms, lubrication points, locations for changing oil in gear boxes (cases), and turntables must be accessible.
2. Weirs, launders and control boxes must be accessible for cleaning, painting and other maintenance activities.
3. Sludge pumps must be conveniently located and capable of backflushing pipelines or pumping down clarifiers.
4. Provisions should be made for connections and/or locations for portable pumps to dewater clarifiers if clarifiers are not connected to plant drainage system.
5. Influent and effluent pipelines, conduits or channels must be installed so that each end can be isolated and dewatered by gravity drain or portable pump.
6. Sludge and scum lines to pump suctions must be kept as short as possible and free of fittings (90-degree bends and reducers).
7. Cleanouts are required on sludge and scum lines to provide access for cleaning equipment such as sewer rods and high velocity cleaners. Cleanouts should be installed in the lines at locations that allow the lines to be worked on while the clarifier remains in service, instead of having to dewater the clarifier to clear a stoppage or clean a line.
8. Auxiliary service lines (water, air, electrical, instrumentation, sample and chemical feed) should be studied. These lines should have isolation valves (to valve off portions of lines) at appropriate locations and should be accessible for repairs when necessary. Conduits for instrumentation, electrical wiring and cables should be equipped with pull boxes that are *WATERTIGHT*. Sample lines should have cleanouts and valving to allow for periodic flushing of the lines. Air lines must be equipped with condensate drains at all low points, including the ends of the line.
9. Covered clarifiers should contain lightweight openings to provide easy access to scum channels, skimmers, launders and drive mechanism units.

5.72 Safety

1. Clarifiers must be equipped with adequate access by stairs, ladders, ramps, catwalks and bridges with railings that meet all state and OSHA requirements.
2. Catwalks and bridges must have floor plates or grates firmly secured and equipped with toeboards and nonskid surfaces.
3. Adequate lighting must be provided on the clarifier.
4. Launders, channels and effluent pipelines that carry flow from the clarifier to another conduit, channel or structure must have safety grates over the entrance to prevent accidental entry into the system caused by slipping or falling.
5. In a circular clarifier, turntables, inlet adjustable deflection baffles and return sludge-control valves must have safe access without requiring the operator to leave a bridge or catwalk.
6. Adequate guards must be placed over chain drives, belts and other moving parts.
7. Safety hooks, poles, and/or floats should be stationed at strategic locations near every basin to rescue anyone who falls into a basin.
8. Do not allow any pipes or conduits to cross on top of catwalks or bridges.
9. Adequate offset of drive units, motors, and other equipment must be provided to allow unobstructed access to all areas.

5.8 FLOTATION PROCESSES

Wastewater always contains some suspended solids that neither settle nor float to the surface and therefore remain in the liquid as it passes through the clarifier. Dissolved solids will, of course, travel through the clarifiers because they are unaffected by these units. *COLLOIDS* and *EMULSIONS* are two other forms of solids that are very difficult to remove.

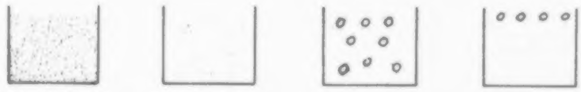


Colloids (KOL-loids) are very small, finely divided solids (particulates that do not dissolve) that remain dispersed in liquid for a long time due to their small size and electrical charge. It is usually less than 200 *MILLIMICRONS*[27] in size, and generally will not settle readily. If organic, it exerts a high oxygen demand, so its removal is desirable.

An emulsion is a liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid held in suspension in the other. It usually contains suspended globules of one or more of the substances. The globules usually consist of grease, oil, fat, or resinous substances. This material also exerts a high oxygen demand.

One method for removing emulsions and colloids is by a "flotation process," pumping air into the mixture to cause the suspended material to float to the surface where it can be skimmed off.

The particles can be *FLOCCULATED*[28] with air or chemical *COAGULANTS*[29] and forced or carried to the liquid surface by minute air bubbles. Figure 5.14 shows the chain of events in the flotation process.



SMALL PARTICLES WILL NOT SETTLE.

SMALL PARTICLES IN FLOCCULATED FORM.

FLOCCULATED PARTICLES ATTACHED TO AIR BUBBLES. BUBBLES CARRY PARTICLES TO SURFACE.

ACCUMULATED SCUM OR FOAM ON SURFACE. MOST AIR BUBBLES ARE RELEASED.

Fig. 5.14 Flotation process

Most of the air bubbles are released at the liquid surface. Particles in the form of scum or foam are removed by skimming.

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[27] *Millimicron (MILL-e-MY-cron). One thousandth of a micron or a millionth of a millimeter.*

[28] *Flocculated (FLOCK-you-lay-ted). The gathering together of fine particles to form larger particles.*

[29] *Coagulants (ko-AGG-you-lents). Chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.*

There are two common flotation processes in practice today:

1. *VACUUM FLOTATION.* The wastewater is aerated for a short time in a tank where it becomes saturated with dissolved air. The air supply is then cut off and large air bubbles pass to the surface and into the atmosphere. The wastewater then flows to a vacuum chamber which pulls out dissolved air in the form of tiny air bubbles. The bubbles then float the solids to the top.
2. *PRESSURE FLOTATION.* Air is forced into the wastewater in a pressure chamber where the air becomes dissolved in the liquid. The pressure is then released from the wastewater, and the wastewater is returned to atmospheric pressure. Because of the change in pressure, the dissolved air is released from solution in the form of tiny air bubbles. These air bubbles rise to the surface and, as they rise, carry solids to the surface.

Any flotation process is based upon release of gas bubbles in the liquid suspension (Fig. 5.14) under conditions in which the bubbles and solids will associate with each other to form a combination with a lower specific gravity than the surrounding liquid. They must stay together long enough for the combination to rise to the surface and be removed by skimming.

For more detailed information on the operation of flotation processes and gravity thickeners, see Chapter 22, "Solids Handling and Disposal."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 147 and 148.

5.7A What safety items should be considered when reviewing plans and specifications for clarifiers?

5.8A Why is the "flotation process" used in some wastewater treatment plants?

5.8B Would you place the flotation process *BEFORE* or *AFTER* primary sedimentation?

5.8C Give a very brief description of:

1. Colloid
2. Emulsion

5.8D Give a brief description of the vacuum flotation process.

END OF LESSON
2
OF
3
LESSONS

on
SEDIMENTATION AND FLOTATION

Please answer the discussion and review questions before continuing with Lesson 3.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 3 Lessons)

Chapter 5. SEDIMENTATION AND FLOTATION

Please write the answers to these questions in your notebook before continuing with Lesson 3. The problem numbering continues from Lesson 1.

9. Explain how temperature influences clarifier performance.
10. Draw a clarifier and indicate what is meant by short-circuiting.
11. A circular primary clarifier has a diameter of 60 feet and an average depth of 8 feet. The flow of wastewater is 2.0 MGD. Calculate the following:
    1. Detention Time, in hours
    2. Weir Overflow Rate, in gpd/ft
    3. Surface Loading Rate, in gpd/sq ft
    4. Comment on the hydraulic loading on the clarifier.
12. If the circular clarifier in problem 11 receives a plant flow of 2.0 MGD plus a return sludge flow of 0.4 MGD, what is the solids loading in lbs/day/sq ft if the mixed liquor suspended solids concentration is 3600 mg/*L*?
13. What items would you study when reviewing plans and specifications for clarifiers?
14. Why should floatable solids be removed from wastewater?

CHAPTER 5. SEDIMENTATION AND FLOTATION

(Lesson 3 of 3 Lessons)

5.9 COMBINED SEDIMENTATION - DIGESTION UNIT

5.90 Purpose of Unit

A combined sedimentation-digestion unit consists of a small clarifier constructed over a sludge digester (Figures 5.15 and 5.16 and Table 5.3). Treatment units of this type have been designed and constructed to serve small populations such as schools, campgrounds and subdivisions. Usually they are installed instead of Imhoff tanks or septic tank systems. Wastewater treatment efficiencies are similar to primary clarifiers with approximately 65 percent of the suspended solids and 35 percent of the biochemical oxygen demand removed from the influent.

5.91 How the Unit Works

The combined sedimentation-digestion unit is considered a *PACKAGE TREATMENT PLANT*.[30] Plant influent usually passes through some type of flow meter to record flows. A bar screen is often the first treatment unit of the package. Coarse solids are caught by the bar screen and removed manually on a daily basis or more often if necessary. Wastewater enters the clarifier near the surface in the center and the circular influent well directs the flow and solids towards the bottom of the clarifier. Settled wastewater slowly flows through the clarifier and leaves over the effluent weir around the outside of the clarifier. The effluent leaves the unit by the effluent trough (launder) and usually receives additional treatment in a secondary package plant (Chapter 8, "Activated Sludge"), ponds (Chapter 9, "Waste Treatment Ponds"), or land treatment disposal system (Chapter 7, "Wastewater Reclamation," *ADVANCED WASTE TREATMENT*).

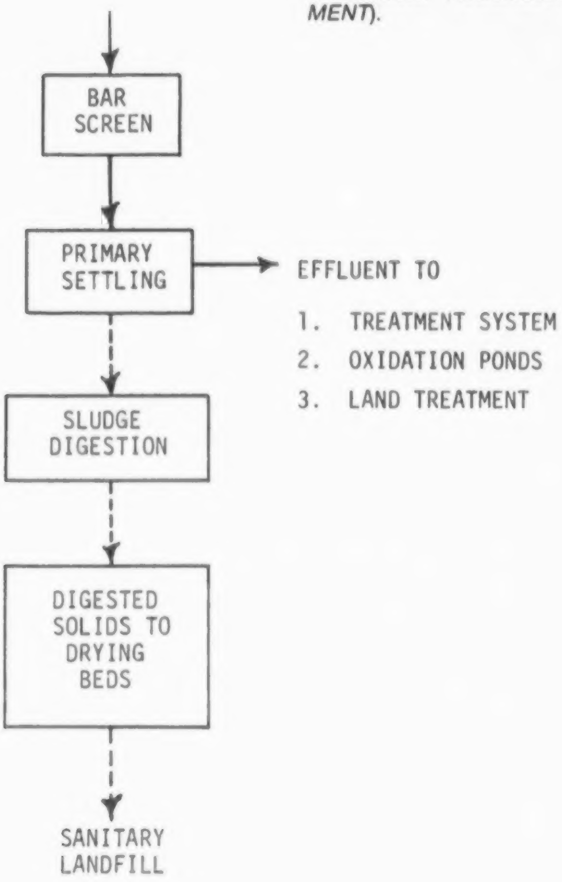

Fig. 5.15 Flow pattern for combined sedimentation-digestion unit

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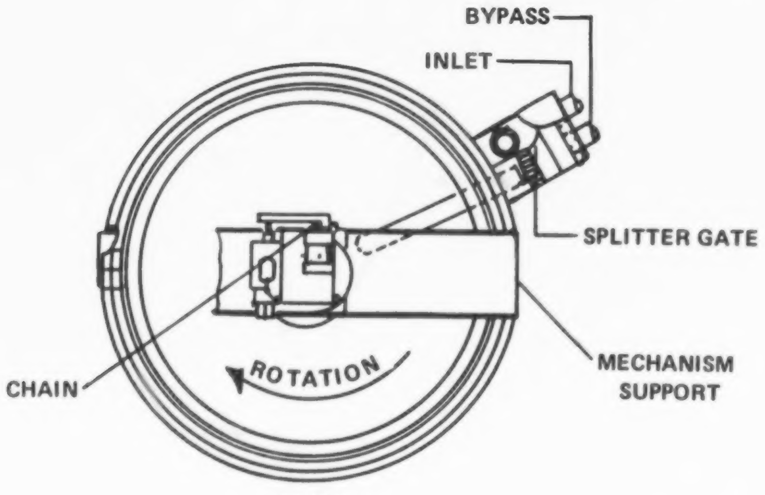
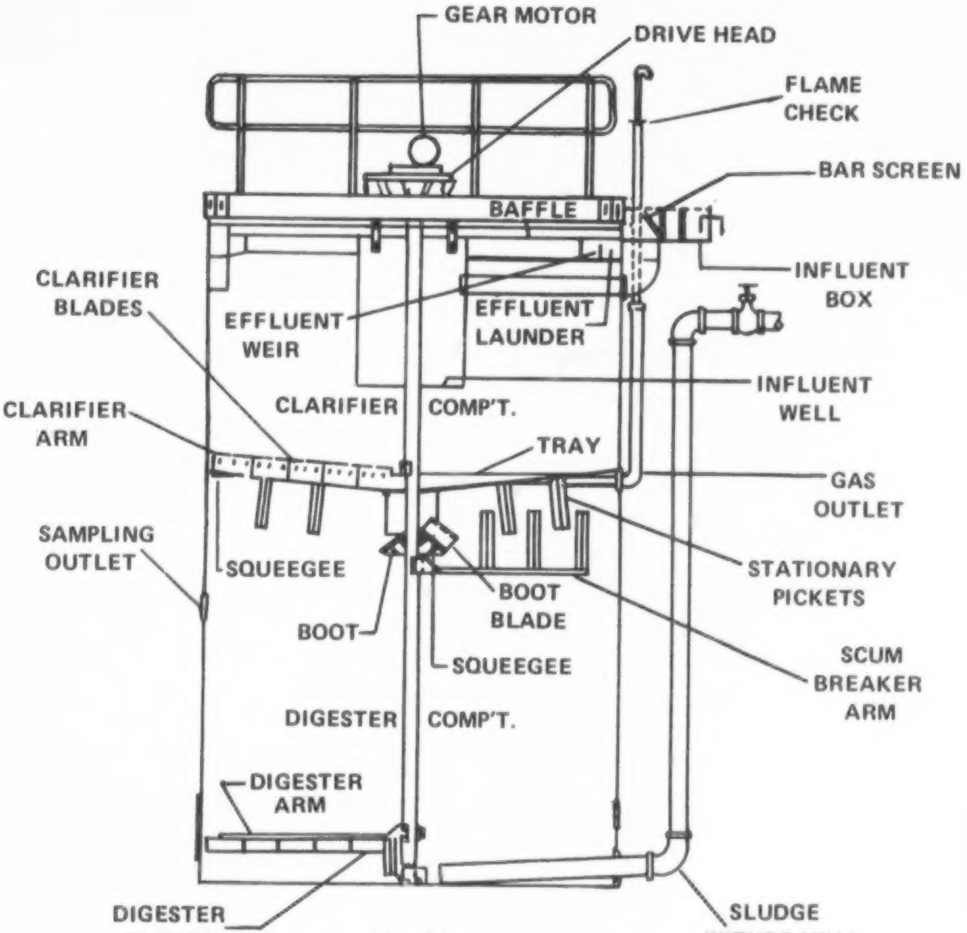
[30] *Package Treatment Plant. A small wastewater treatment plant often fabricated at the manufacturer's factory, hauled to the site, and installed as one facility. The package may be either a small primary or secondary wastewater treatment plant.*


BYPASS
INLET
SPLITTER GATE
MECHANISM SUPPORT
CHAIN
ROTATION

PLAN


GEAR MOTOR
DRIVE HEAD
FLAME CHECK
BAR SCREEN
BAFFLE
INFLUENT BOX
CLARIFIER BLADES
EFFLUENT WEIR
EFFLUENT LAUNDER
INFLUENT WELL
CLARIFIER COMP'T.
CLARIFIER ARM
TRAY
GAS OUTLET
SAMPLING OUTLET
SQUEEGEE
STATIONARY PICKETS
BOOT BLADE
BOOT
SQUEEGEE
SCUM BREAKER ARM
DIGESTER COMP'T.
DIGESTER ARM
DIGESTER BLADES
SLUDGE WITHDRAWAL

SECTION

Fig. 5.16 Combined sedimentation-digestion unit

(Permission of Dorr-Oliver Incorporated)

TABLE 5.3 PURPOSE OF SEDIMENTATION-DIGESTION UNIT AND PARTS

Part	Purpose
1. Bar Screen	Removes coarse material to prevent clogging of pipes or interference with mechanical units such as scrapers and pumps.
2. Flame Check	Prevents flame from traveling down gas outlet pipe to top of digester compartment where a flame could cause an explosion.
3. Gear Motor	Provides power to turn the scraper blades in the bottom of both the clarifier and the digester.
4. Clarifier Arm and Blades	Scrapes the settled solids (sludge) to a center hole where the sludge enters the digester.
5. Clarifier Compartment	Provides storage space for wastewater being treated and allows heavy solids to settle to the bottom and light solids to float to the surface.
6. Digester Arm and Blades	Scrapes the digested sludge on the digester bottom to the sludge withdrawal pipe.
7. Effluent Launder or Effluent Trough	Conveys the settled wastewater away from the clarifier.
8. Scum Breaker Arm and Stationary Pickets	Breaks up scum accumulation in the top of the digester compartment.
9. Digester Compartment	Provides storage space for sludge, allows digestion to occur and the separation of liquids and solids for disposal.
10. Sampling Outlet	Allows withdrawal of digester sludge for laboratory testing.
11. Sludge Withdrawal	Allows digested sludge to be removed from digester.

Solids settling to the bottom of the clarifier (tray) are scraped to the center of the unit. A slot in the center of the tray allows the solids to flow into the digestion compartment. Below the slot is a sludge seal or boot which prevents gas from digestion and digested sludge from floating up into the clarifier. In the digester, sludge undergoes anaerobic decomposition (explained in Chapter 12). Digested sludge is removed from the bottom of the digester by pumping or by gravity flow to drying beds.

Scum is skimmed from the surface of the clarifier into a scum trough. From the trough, the scum flows to the scum pit (Fig. 5.17). A submersible pump moves the scum to the digestion compartment.

Supernatant (the liquid in the top portion of the digester) is removed from the digester by lowering an adjustable overflow tube (Fig. 5.17) and allowing the liquid to flow into the scum pit. Again the submersible pump moves the supernatant to the clarifier influent well and the supernatant flows through the clarifier.

Gas from the digestion process rises to the top of the digester as tiny bubbles. The tray (bottom of clarifier) slopes upward to the outside. This slope helps move sludge to the center slot and allows gas to accumulate along the outside edge of the digestion portion of the unit. The gas is collected in a gas dome and usually burned by a waste-gas burner. Sufficient gas is not produced to serve as a reliable source of energy for power or for heating.

5.92 Sampling and Analysis

Sampling locations and laboratory tests performed depend upon NPDES (National Pollutant Discharge Elimination System) permit requirements, available time and capability of facility to make operational changes on the basis of the interpretation of test results. Typical tests, their purposes and expected ranges of test results are listed in Table 5.4.

5.93 Operation

5.930 Start-Up Procedures

Always thoroughly inspect the entire unit before allowing wastewater to enter. Any corrections will be more difficult after the unit is full of wastewater.

1. Remove all debris and tools from unit.
2. Follow the wastewater and solids flow paths through the unit (Section 5.91). Be sure you understand how the unit works and what happens when all the valves and switches are either open or closed.
3. Lubricate all equipment.
4. Allow unit to run for two hours.
5. Observe operation of unit. Be sure all equipment has proper alignment and clearance.
6. Keep all bolts tight.
7. Divert wastewater to unit.
8. Allow unit to fill and clarified effluent to flow over effluent weirs.
9. Inspect tank and pipes for leaks.
   Repair any leaks. If unit has not been previously tested for leaks, allow unit to sit for 24 hours without any influent. If water level drops more than one inch, find leak and repair it.
10. Make sure pipes are not plugged.
11. Operate valves to be sure they operate freely and are watertight.
12. Leave dome vent open until gas production starts. Vent must be open to atmosphere to prevent gases from accumulating in confined spaces. Time for gas production to start will depend on temperature of sludge under digestion. The warmer the sludge, the shorter the time. Gas will start being produced anytime after the first three weeks.
13. Chlorinate final effluent.
14. Add lime to digestion unit if pH is below 7.0. Sample supernatant by lowering adjustable overflow tube in scum pit and measuring pH (See Chapter 16 for procedure). If the pH is closely controlled, these units may be started without seeding with digested sludge. Lime should be added on the *VERY FIRST DAY DURING START-UP* and daily until the pH remains above 7.0. Recommended lime doses are as follows:

TABLE 5.4 COMBINED SEDIMENTATION-DIGESTION UNIT TESTS, PURPOSES AND RESULTS

Test	Typical Results	Purpose
1. Inflow, MGD	Depends on population served. May range from 80 to 130 gallons per person per day.	Determine hydraulic loading on facility. Identify flow trends and when facility is approaching design capacity.
Clarifier		
2. Suspended Solids	(Infl) 100 - 300 mg/*L* (Effl) 50 - 100 mg/*L*	Indicates efficiency of clarifier removal.
3. Settleable Solids	(Infl) 50 - 100 ml/*L* (Effl) 5 -15 ml/*L*	Indicates efficiency of clarifier removal.
4. Biochemical Oxygen Demand (BOD) (Optional)	(Infl) 150 - 300 mg/*L* (Effl) 100 - 200 mg/*L*	Indicates efficiency of clarifier removal.
Digestion		
5. Temperature	Depends on location, season and whether or not sludge is heated.	Forecasts digestion rates which depend on temperature of digesting sludge.
6. pH	7.0 - 7.6	Determines if effective digestion is taking place. Too low a pH value indicates poor digestion.
7. Quantity of sludge withdrawn	Depends on population, detention time in digester and temperature.	Determines effectiveness of clarifier in removing solids and effectiveness of digester in reducing solids.
Effluent (from final treatment process)		
8. Chlorine residual	Depends on NPDES permit requirements.	Determines if sufficient chlorine is being applied to effluent to achieve adequate disinfection.

Laboratory tests should be conducted on a regular basis from twice a week to daily depending on NPDES permit requirements. Results should be plotted (Fig. 5.18) immediately to identify any trends that need correcting.

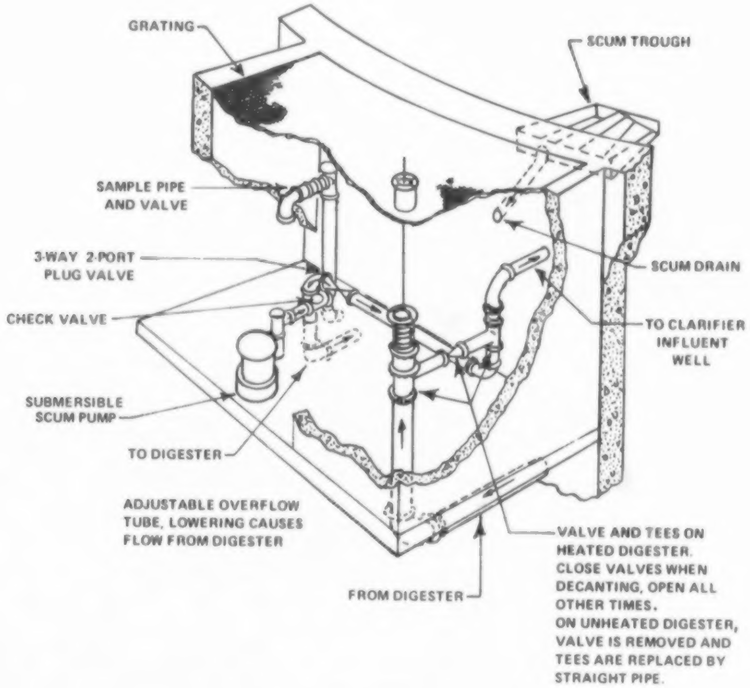

GRATING
SCUM TROUGH
SAMPLE PIPE AND VALVE
3-WAY 2-PORT PLUG VALVE
SCUM DRAIN
CHECK VALVE
TO CLARIFIER INFLUENT WELL
SUBMERSIBLE SCUM PUMP
TO DIGESTER
ADJUSTABLE OVERFLOW TUBE, LOWERING CAUSES FLOW FROM DIGESTER
VALVE AND TEES ON HEATED DIGESTER. CLOSE VALVES WHEN DECANTING, OPEN ALL OTHER TIMES. ON UNHEATED DIGESTER, VALVE IS REMOVED AND TEES ARE REPLACED BY STRAIGHT PIPE.
FROM DIGESTER

Fig. 5.17 Arrangement of scum pit piping
(Permission of Dorr-Oliver Incorporated)

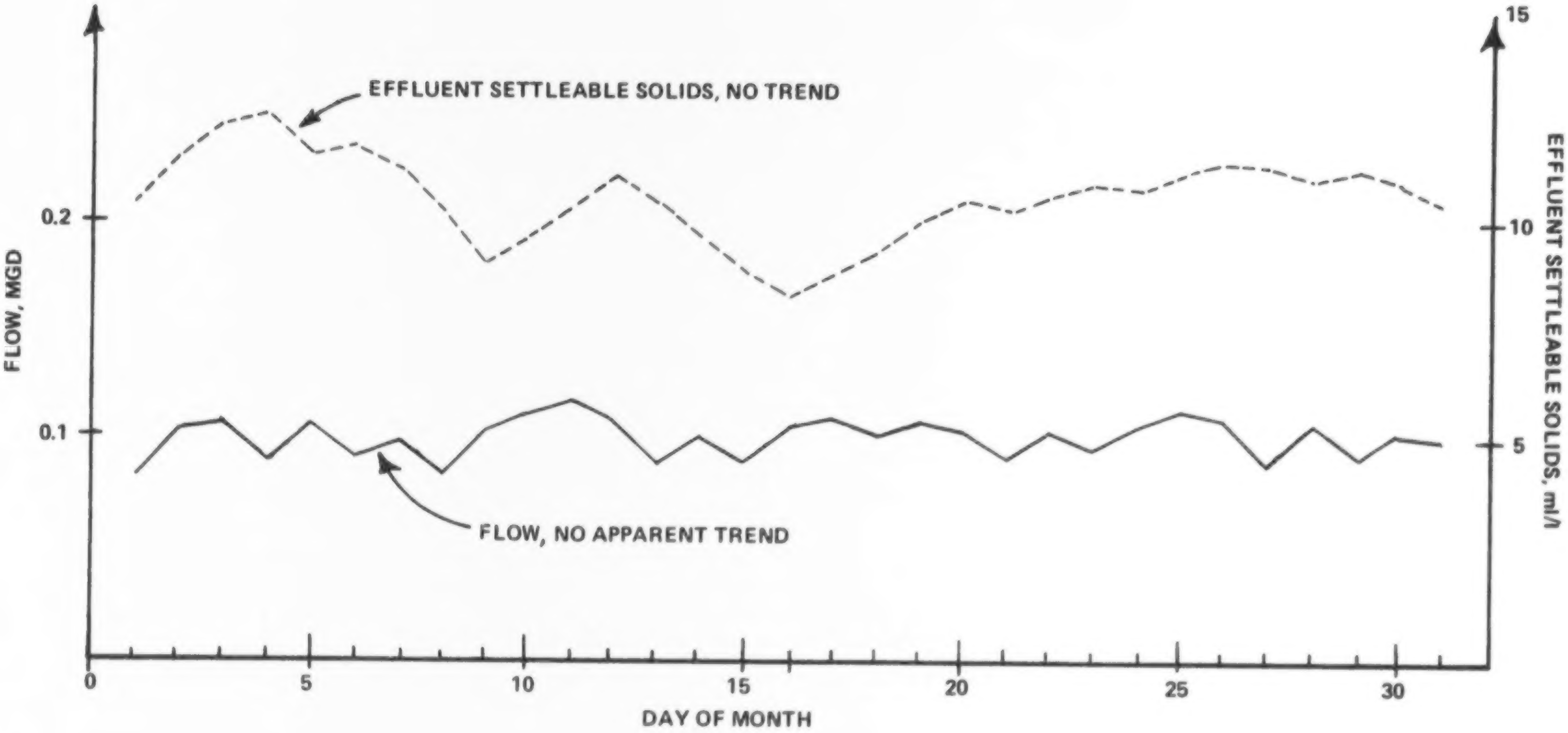


Fig. 5.18 Plot of lab results to identify any trends

Diameter of Unit, ft	Hydrated Lime, lbs	Water, Gallons	Frequency
10-18	25	30	Every 2 days
20-28	25	50	Every day
30-40	50	100	Every day

Mix the lime with water in a barrel until milky. Pour mixture into scum pit and then pump into digestion unit using submersible pump. Be sure valves are properly set so mixture is not pumped into clarifier. Allow some wastewater to flow from influent of clarifier into scum pit (or washdown hose may be used to add water to scum pit). Pump out scum pit and wash down to remove any remaining lime to digestion unit. Stop adding lime when pH remains above 7.0.

Another chemical used to raise the pH is anhydrous ammonia. Be sure to handle anhydrous ammonia very carefully because it is a hazardous chemical.

5.931 Normal Operation

Normal operation consists of inspecting the unit on a daily basis. Observe the flow through the facility and the operation of the equipment. Look and listen for anything unusual.

DAILY

1. Remove debris and solids from bar screen and properly dispose of them by burial. Hose down screen and channel walls.
2. Hose down baffles, weirs, scum trough and scum pit to remove any grease, scum or other floating debris. Accumulations of this material are unsightly and usually produce odors and flies if not removed immediately.
3. Measure pH in digester. If pH is below 7.0, add lime according to start-up instructions. If pH remains fairly constant and above a pH of 7.0, pH may be measured two or three times per week.
4. Withdraw supernatant once or twice a day. Analysis and interpretation of lab test results of suspended solids and settleable solids in effluent can indicate the frequency of supernatant withdrawal. Solids in the effluent may indicate that supernatant should be removed more frequently.

   Supernatant is withdrawn from the digestion compartment by lowering the sleeve on the overflow tube in the scum box. When the top of the sleeve is below the water surface in the clarifier, the supernatant will flow out of the digestion compartment. Removal of the supernatant provides more space in the digester for sludge being scraped from the bottom (tray) of the clarifier.

   Lower the sleeve so approximately one-half inch of water will flow over the top of the sleeve for 15 to-30 minutes twice a day.
5. After supernatant withdrawal to the scum pit, pump the clear supernatant to the clarifier. When most of the supernatant has been pumped out of the pit, only scum will remain. Pump the scum to the digester. *DO NOT ALLOW THE SUBMERSIBLE SCUM PUMP TO RUN DRY* because the pump motor can be damaged. Pump the scum frequently enough to prevent odors from developing or flies becoming nuisances. If the supernatant is high in solids, return the supernatant to the digester. Try to prevent supernatant solids from flowing out with the clarifier effluent. Solids may be in the supernatant during initial start-up. Under these conditions, the supernatant may be pumped to drying beds until the digester solids in the supernatant can indicate that the digested solids should be removed from the digestion compartment (digester).
6. Digested sludge should be withdrawn from the digester when solids start appearing in the supernatant. This will occur several months after start-up and regularly during normal operation. Frequency of digested-sludge removal will depend on the solids loading on the unit, design capacity and effectiveness of the digestion process in the unit. The scraper mechanism on the bottom of the digester helps to prevent sludge coning during sludge withdrawal.

   Withdraw the sludge slowly so the sand and other grit on the bottom of the digestion unit will be removed too. Do not remove sludge so fast that the clarified effluent will stop flowing over the effluent weirs. If the digested sludge is allowed to flow out too quickly, the sludge directly above the sludge-withdrawal pipe will flow out. A cone will develop in the sludge and the supernatant will flow out rather than allowing the remaining digested sludge to flow towards the withdrawal pipe.

   Always leave some digested sludge remaining in the digestion compartment. As soon as the sludge starts to run thin, stop removing sludge. If a cone has developed and a lot of digested sludge remains, try removing some supernatant to the scum pit and pumping it back to the digestion compartment. One way to avoid withdrawing too much digested sludge is to only remove a portion of the sludge from the digester during one day. For example, if 1/40th of the sludge from the digestion compartment will cover the sludge drying beds with 3 inches (7.5 cm) of sludge, then do not withdraw more than this amount on any given day.

   When you are through removing digested sludge, wash out the line with plant effluent. Shut the valve by the digestion compartment and leave the remainder of the line open so gas produced from digestion will not cause a pressure buildup which could damage the pipe or valves.

Usually the digested sludge is discharged to sand drying beds (Chapter 12). After the sludge is dried, it can be removed and disposed of in a sanitary landfill.

Do not smoke around drying beds while the digested sludge is being applied. Methane gas can mix with air to form explosive conditions.

If odors develop from the drying bed, a neutral *MASKING AGENT*[31] may be applied. Lime also has been used to control odors.

---

[31] *Masking Agents. Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.*

7. In colder climates the contents of the digester may be heated in order to obtain better and faster digestion. Try to maintain the temperature of the digester contents between 80 and 95°F (27 and 35°C). The closer to 90°F (32°C), the faster the rate of digestion.

8. Gas production will not start until solids digestion starts in the digester. The gas line should be equipped with a moisture trap and a flame arrester, and connected to a waste gas burner.

   Be sure the gas line is clear. Scum and undigestible material can prevent gas from flowing from the digestion compartment. If necessary, remove this scum and debris.

   Once sufficient methane gas is produced, the waste gas should be burned.

9. *PROBLEM*. Floating sludge on clarifier surface.

   Floating sludge may result from sludge not passing from bottom of clarifier, around the sludge seal, and into the sludge digester.

   a. Try withdrawing more supernatant so the sludge can flow into the digester.
   b. Shut off the sludge scraper. Check the sludge seal by "feeling" with a pole or rod to remove any screenings or other objects which might be plugging the hole.
   c. Pump less scum or supernatant into the digester. Excessive pumping may be forcing sludge out of the digestion compartment.

5.932 *Abnormal Operation*

Abnormal operation occurs when:

1. Inflows are higher than design flows due to storm water inflow and infiltration.
2. Solids loadings are high due to seasonal or industrial discharges, and
3. Toxic substances or high or low pH liquids are released into the collection system.

With a single combined sedimentation-digestion unit, there is little an operator can do in terms of adjusting valves or directing flows. If abnormal conditions occur occasionally and upset the clarifier and/or the digestion unit, provisions should be made to construct an emergency pond to hold the abnormal flows and substances until they can be treated by the unit during low flow periods.

5.933 *Shutdown Procedures*

The unit should be shut down annually for inspection, maintenance and repair. If there is only one unit for treating the wastewater, a standby emergency pond should be available to contain the wastewater during shutdown. Schedule shutdown during periods of expected low flows. Shutdown procedures are as follows:

1. Divert flow to other units or to standby pond.
2. Drain clarifier and digester to drying beds.
3. Wash down inside of unit.
4. Inspect facility. Be sure facility is adequately ventilated and test for toxic gases, explosive conditions and sufficient oxygen. Look for
   a. Corrosion damage
   b. Unpainted surfaces
   c. Worn parts
   d. Cracks and leaks
5. Make necessary repairs.
6. Follow start-up procedures to place unit back on line.

5.934 *Operational Strategy*

With only one unit, the operator must try to treat the entire flow. If inflows do not exceed design capacity, problems should not develop.

1. Follow normal operational procedures.
2. Collect and analyze samples on a regular basis.
3. Plot results of tests and look for trends.
4. Make any necessary adjustments.
5. Maintain all equipment according to schedule.

5.94 Maintenance

1. Lubricate all equipment in accordance with manufacturers' recommendations.
2. If any tools or other objects fall into clarifier, stop rotation and remove the tool or object.
3. If scraper mechanism stops moving, determine cause and remove it before attempting to start mechanism again. DO NOT TAMPER WITH THE OVERLOAD SWITCH ADJUSTMENTS IN AN ATTEMPT TO FORCE THE MACHINE TO OPERATE AGAINST THE OVERLOAD.

5.95 Safety

1. Be careful when removing debris from open tanks. Secure firm footing so you won't slip or fall. Do not try to lift more than you can safely lift.
2. Be sure all moving machinery parts have covers or guards.
3. Be aware of the fact that *DIGESTER GAS* is *VERY TOXIC OR POISONOUS*. When mixed with air this gas can *BURN* or *EXPLODE*. Everyone must strictly observe the following rules:
   a. Post a danger sign near the gas dome indicating "DANGER. NO SMOKING OR OPEN FLAMES."
   b. Keep all lighted cigars, cigarettes, pipes or any open fire away from the digester or digester gas at all times.
   c. Do not inhale digester gas.
   d. Do not enter the digestion compartment unless it is empty of all sludge and forced ventilation has cleared it of gas. Remember that any gas mask must have a self-contained supply of oxygen for you to breathe.
   e. Remove all oil and grease spills and other slippery matter from surfaces.

5.96 Acknowledgment

The authors wish to thank Dorr-Oliver Incorporated for allowing the use of their material for the preparation of this section.

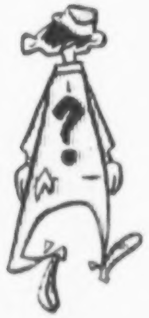
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 148.

5.9A What is a combined sedimentation-digestion unit?

5.9B What abnormal operating conditions might the operator of a combined sedimentation-digestion unit encounter?

5.9C List the major maintenance items for a combined sedimentation-digestion unit.



5.10 IMHOFF TANKS

Imhoff tanks are rarely constructed today. Your plant may consist of *ONLY* an Imhoff tank if it serves a very small community or if it was constructed many years ago. It is quite possible that you may never have operating responsibility for one of these units. They will be discussed for general knowledge and for the few operators who will have operating responsibility for them.

The Imhoff tank combines sedimentation and sludge digestion in the same unit. There is a top compartment where sedimentation occurs and a bottom compartment for digestion of settled particles (sludge). The two compartments are separated by a floor with a slot designed to allow settling particles to pass through to the digestion compartment (Fig. 5.19).

Wastewater flows slowly through the upper tank as in any other standard rectangular sedimentation unit. The settling solids pass through the slot to the bottom sludge-digestion tank. Anaerobic digestion of solids is the same as in a separate digester. Gas bubbles are formed in the digestion area by bacteria. As the gas bubbles rise to the surface, they carry solid particles with them. The slot is designed to prevent solids from passing back into the upper sedimentation area as a result of gasification. Solids would flow from the unit with the effluent if they were permitted to pass back into the upper sedimentation area.

The same calculations previously used for clarifiers can be used to determine loading rates for the settling area of the Imhoff tank. (Chapter 12, "Sludge Digestion," will explain the anaerobic process in the sludge digestion area of this unit.) Some typical values for design and operation of Imhoff tanks are:

Settling Area

Wastewater Detention Time — 1.0 to 4.0 hours
Surface Settling Rate — 600 to 1200 gpd/sq ft
Weir Overflow Rate — 10,000 to 20,000 gpd/ft
Suspended Solids Removal — 45% to 65%
BOD Removal — 25% to 35%

Digestion Area

Digestion Capacity — 1.0 to 3.0 cu ft/person
Sludge Storage Time — 3 to 12 months

Here are a few operational suggestions:

1. In general, there is no mechanical sludge-scraping device for removing settled solids from the floor of the settling areas. Solids may accumulate before passing through the slot to the digestion area. It may be necessary to push the accumulation through the slot with a squeegee or similar device attached to a long pole. Dragging a chain on the floor and allowing it to pass through the slot is another method for removing the sludge accumulation.
2. Scum from the sedimentation area is usually collected with hand tools and placed in a separate container for disposal. Scum also may be transferred to the gas venting area where it will work down into the digestion compartment. Scum in the gas vents should be kept soft and broken up by soaking it periodically with water or by punching holes in it and mixing it with the liquid portion of the digestion compartment. The addition of hydrated lime may be helpful for controlling odors from the gas vent area and also for adjusting the chemical balance of the scum for easier digestion if necessary.

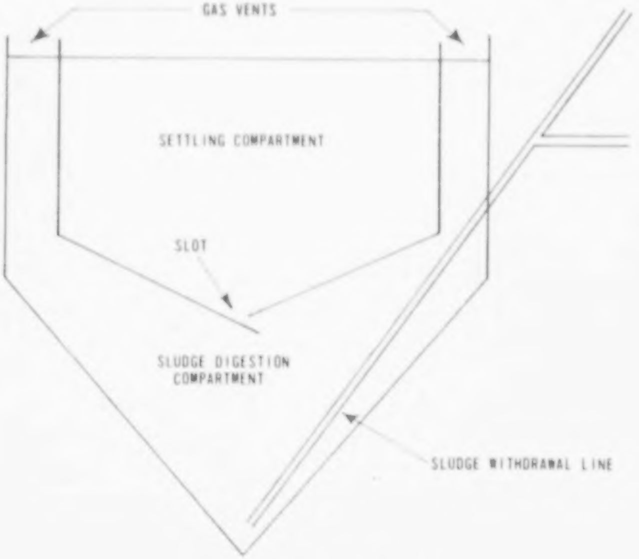


Fig. 5.19 Imhoff tank

3. Some Imhoff tanks have the piping and valving to reverse the direction of flow from one end toward the other end. If possible, the flow should be reversed periodically for the purpose of maintaining an even sludge depth in the digestion compartment. The sludge level in the digestion area must be lower than the slot in the floor of the settling area to prevent plugging of the slot. A line of gas bubbles directly over the slot indicates the sludge level in the digestion chamber is too high.
4. The explanation of sludge digestion in Chapter 12 will supply information that can be applied to the digestion area in the Imhoff tank. Neither sludge mixing nor heating devices are used in an Imhoff tank. Sludge loading rates, withdrawal rates, laboratory tests, and visual appearance of sludges are very similar to what they are in an *UNHEATED* digester. If visual appearance and smell are the only methods you have of judging the sludge, it is safe to assume that if sludge in the digestion area is relatively odorless or has a musty smell and is black or very dark in color, the process is working satisfactorily.

The laboratory testing program for an Imhoff tank should be complete enough to identify operational problems and to supply necessary information to regulatory agencies. The following minimum program is suggested, assuming adequate laboratory facilities, personnel, and size of the system.

SUGGESTED ANALYSIS	USUAL RANGE	TYPICAL REMOVAL %
Settling Area		
Settleable Solids	3.0 - 10.0 ml/*L*	75 - 90
Suspended Solids	200 - 400 mg/*L*	45 - 65
pH	6.7 - 7.3	
Alkalinity	100 - 300 mg/*L*	
BOD	200 - 500 mg/*L*	25 - 35
Digestion Area		
pH	6.7 - 7.3	
Alkalinity	1000 - 3000 mg/*L*	
Vol. Acids	100 - 500 mg/*L*	

Efficiency of operation can be determined by measuring the settleable solids, suspended solids, or BOD of the influent and effluent.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 148.

5.10A What are the two components of an Imhoff tank?

5.10B Describe the sludge from an Imhoff tank which is operating properly.

5.10C How could you maintain a fairly level sludge blanket in the digester portion of an Imhoff tank?

5.10D How can you force settled material into the digestion compartment?

5.11 SEPTIC TANKS

Septic tanks are used mostly for treating the wastewater from individual homes or from small populations (such as camps) where sewers have not been provided. They operate very much like an Imhoff tank except there is not a separate digestion compartment. Detention time is usually long (12 to 24 hours) and most settleable solids will remain in the tank. They must be pumped out and disposed of periodically to prevent the tank from filling. Part of the solids in the septic tank are liquified and discharged with the wastewater into the soil mantle. Conditions are not favorable for rapid gasification and most waste stabilization occurs in the soil.

Septic tank effluent is usually disposed of in underground perforated pipes called *LEACH LINES*, and sampling of effluent may be impossible. The ability of the soil mantle to leach the septic tank effluent is the critical factor in subsurface waste disposal systems.

One method of operating septic tank effluent leaching systems is to apply effluent to half of the system while the other half rests. Monthly switch the flow from one half to the other half. This procedure gives the leaching system a chance to recover its percolation ability.

5.12 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read the following sections:

1. A.5 Weight-Volume Relations, and
2. A.132 Sedimentation Tanks and Clarifiers.

Check all of the arithmetic in these two sections on an electronic pocket calculator. You should be able to get the same answers.

5.13 ADDITIONAL READING

1. *MOP 11*, Chapter 4, "Sampling of Wastewater" and Chapter 8 "Primary Sedimentation."*
2. *NEW YORK MANUAL*, Chapter 4, "Primary Treatment."
3. *TEXAS MANUAL*, Chapter 11, "Sedimentation."

*Depends on edition

5.14 METRIC CALCULATIONS

This section contains the solutions to all problems in this chapter using metric calculations.

5.140 Conversion Factors

MGD × 3785 = cu m/day
cu m/day × 0.000 264 = MGD
gallons × 3.785 = liters
1000 *L* = 1 cu m
ft × 0.3048 = m
m × 3.281 = ft
cu ft × 0.028 32 = liters
L × 0.035 315 = cu ft

5.141 Problem Solutions

1. The influent BOD to a primary clarifier is 200 mg/*L*, and the effluent BOD is 140 mg/*L*. What is the efficiency of the primary clarifier in removing BOD?

Known	Unknown
Infl. BOD, mg/*L* = 200 mg/*L*	Prim. Clar. Eff., %
Effl. BOD, mg/*L* = 140 mg/*L*	

CALCULATIONS:

1. Calculate the primary clarifier efficiency, %, in removing BOD.

$$\text{Efficiency, \%} = \frac{(\text{In-Out})}{\text{In}} \times 100\%$$

$$= \frac{(200\text{ mg}/L - 140\text{ mg}/L)}{200\text{ mg}/L} \times 100\%$$

$$= \frac{(60\text{ mg}/L)}{200\text{ mg}/L} \times 100\%$$

$$= (0.30)\,(100\%)$$

$$= 30\%\text{ BOD Removal}$$

NOTE: This problem solution is exactly like the solution in the text because the influent and effluent BODs are given in mg/*L* which is the Metric System.

2. The flow to a rectangular sedimentation tank is 12,000 cu m per day. Tank dimensions are 20 meters long by 10 meters wide by 3 meters deep. What is the detention time?

Known		Unknown
Flow, cu m/day	= 12,000 cu m/day	Detention Time, hr
Length, m	= 20 m	
Width, m	= 10 m	
Depth, m	= 3 m	

Formulas:

$$\text{Detention Time, hrs} = \frac{\text{Tank Volume, cu m} \times 24\ \text{hr/day}}{\text{Flow, cu m/day}}$$

$$\text{Tank Vol, cu m} = \text{Length, m} \times \text{Width, m} \times \text{Depth, m}$$[32]

CALCULATIONS:

1. Calculate the tank volume in cubic meters.

$$\begin{aligned}\text{Tank Vol, cu m} &= \text{Length, m} \times \text{Width, m} \times \text{Depth, m}\\ &= 20\ \text{m} \times 10\ \text{m} \times 3\ \text{m}\\ &= 600\ \text{cu m}\end{aligned}$$

2. Estimate the detention time in hours.

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{\text{Tank Volume, cu m} \times 24\ \text{hr/day}}{\text{Flow, cu m/day}}\\ &= \frac{600\ \text{cu m} \times 24\ \text{hr/day}}{12{,}000\ \text{cu m/day}}\\ &= 1.2\ \text{hours}\end{aligned}$$

3. The flow is 20,000 cu m per day in a circular tank with a 30-meter weir diameter. What is the weir overflow rate in cubic meters per day per meter of weir length?

Known		Unknown
Flow, cu m/day	= 20,000 cu m/day	Weir Overflow Rate, cu m/day/m
Weir Diameter, m	= 30 m	

FORMULAS:

$$\text{Weir Overflow Rate, cu m/day/m} = \frac{\text{Flow, cu m/day}}{\text{Length of Weir, m}}$$

$$\text{Length of Circular Weir, m} = \pi \times \text{Weir Diameter, m}$$

CALCULATIONS:

1. Calculate the length of circular weir in meters.

$$\begin{aligned}\text{Length of Circular Weir, m} &= \pi \times \text{Weir Diameter, m.}\\ &= 3.14 \times 30\ \text{m}\\ &= 94.2\ \text{m}\end{aligned}$$

2. Estimate the weir overflow rate in cubic meters per day per meter of weir length.

$$\begin{aligned}\text{Weir Overflow, cu m/day/m} &= \frac{\text{Flow, cu m/day}}{\text{Length of Weir, m}}\\ &= \frac{20{,}000\ \text{cu m/day}}{94.2\ \text{m}}\\ &= 212\ \text{cu m/day/m of weir}\end{aligned}$$

4. The flow into a rectangular clarifier is 15,000 cu m per day in a tank 30 meters long and 10 meters wide. What is the surface loading rate in cubic meters per day per square meter of surface area?

Known		Unknown
Flow, cu m/day	= 15,000 cu m/day	Surface Loading, cu m/day/sq m
Length, m	= 30 m	
Width, m	= 10 m	

FORMULA:

$$\text{Surface Loading, cu m/day/sq m} = \frac{\text{Flow, cu m/day}}{\text{Surface Area, sq m}}$$

CALCULATIONS:

1. Calculate the surface area in square meters.

$$\begin{aligned}\text{Surface Area, sq m} &= \text{Length, m} \times \text{Width, m}^{33}\\ &= 30\ \text{m} \times 10\ \text{m}\\ &= 300\ \text{sq m}\end{aligned}$$

2. Estimate the surface loading in cubic meters per day per square meter of surface area.

$$\begin{aligned}\text{Surface Loading, cu m/day/sq m} &= \frac{\text{Flow, cu m/day}}{\text{Surface Area, sq m}}\\ &= \frac{15{,}000\ \text{cu m/day}}{300\ \text{sq m}}\\ &= 50\ \text{cu m/day/sq m}\end{aligned}$$

5. A circular secondary clarifier with a diameter of 30 meters treats a flow of 17,000 cubic meters per day (13,000 cu m/day inflow and 4,000 cu m/day return sludge flow) with a mixed liquor suspended solids concentration of 4200 mg/*L*. What is the solids loading in kilograms of solids per day per square meter of surface area?

Known		Unknown
Flow, cu m/day	= 17,000 cu m/day	Solids Loading, kg/day/sq m
Diameter, m	= 30 m	
MLSS, mg/*L*	= 4200 mg/*L*	

FORMULAS:

$$\text{Solids Applied, kg/day} = \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \text{MLSS, } \frac{\text{mg}}{L} \times \frac{1000\ L}{1\ \text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}$$

$$\text{Solids Loading, kg/day/sq m} = \frac{\text{Solids Applied, kg/day}}{\text{Surface Area, sq m}}$$

CALCULATIONS:

1. Calculate the solids applied in kilograms per day.

$$\begin{aligned}\text{Solids Applied, kg/day} &= \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \text{MLSS, } \frac{\text{mg}}{L} \times \frac{1000\ L}{1\ \text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}\\ &= 17{,}000\ \frac{\text{cu m}}{\text{day}} \times 4200\ \frac{\text{mg}}{L} \times \frac{1000\ L}{1\ \text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}\\ &= 71{,}400\ \text{kg/day}\end{aligned}$$

---

[32] *For a circular clarifier,*
Tank Vol, cu m = 0.785 × (Diameter, m)^2 × Depth, m

[33] *For a circular clarifier,*
Surface Area, sq m = 0.785 × (Diameter, m)^2

2. Calculate the surface area in square meters.

$$\text{Surface Area, sq m} = \frac{(\pi)}{4}(\text{Diameter, m})^2$$

$$= \frac{(3.14)}{4}(30\text{ m})^2$$

$$= 706.5\text{ sq m}$$

3. Estimate the surface loading in kilograms of solids per day per square meter of surface area.

$$\text{Solids Loading, kg/day/sq m} = \frac{\text{Solids Applied, kg/day}}{\text{Surface Area, sq m}}$$

$$= \frac{71{,}400\text{ kg/day}}{706.5\text{ sq m}}$$

$$= 101\text{ kg/day/sq m}$$

END OF LESSON 3 OF 3 LESSONS

on
SEDIMENTATION AND FLOTATION

Please answer discussion and review questions before working the Objective Test.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 3 Lessons)

Chapter 5. SEDIMENTATION AND FLOTATION

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 2.

15. How does a combined sedimentation-digestion unit work?

16. What would you do if floating sludge appeared on the surface of a combined sedimentation-digestion unit?

17. What is the critical factor in subsurface wastewater disposal systems?

SUGGESTED ANSWERS

Chapter 5. SEDIMENTATION AND FLOTATION

Answers to questions on page 115.

5.0A The main difference between the effluent from primary and secondary clarifiers is that the effluent from a secondary clarifier is normally clearer than primary effluent.

5.0B The main difference between the sludge from primary and secondary clarifiers is that primary sludge is usually denser than secondary sludge.

5.1A Significant check items before starting a circular clarifier include:

1. Control gates for operation,
2. Clarifier tank for sand and debris,
3. Collector drive mechanism for lubrication, oil level, drive alignment, and complete assembly,
4. Gaskets, gears, drive chain sprockets and drive motor for proper installation and rotation,
5. Squeegee blades on the collector plows for proper installation and operation,
6. All other mechanical items below water line for proper installation and operation,
7. Tank sumps or hoppers and return lines for debris and obstructions, and
8. Tank structure for corrosion, cracks and other indications of structural failure.

5.1B When the crosspieces in a rectangular clarifier are not straight across the tank, sludge will be piled higher on the trailing side and/or the crosspieces will hang up and cause severe damage to the flight.

5.1C Safety precautions that should be taken during start-up include:

1. Wear a hard hat when down in the tank for protection from falling objects;
2. Keep hands away from moving equipment; and
3. When working on equipment, be sure to red tag and use a lock-out device on start-stop switches and influent control gates to prevent equipment from starting unexpectedly and causing equipment damage and/or personal injury.

Answers to questions on page 121.

5.2A Settleable solids, suspended solids, total solids, BOD, and coliform group bacteria.

5.2B 90% to 99%.

5.2C Influent and effluent.

5.2D

$$\text{Efficiency, \%} = \frac{(\text{In - Out})}{\text{In}}\ 100\%$$

$$= \frac{(300\text{ mg}/L - 120\text{ mg}/L)}{300\text{ mg}/L}\ 100\%$$

$$= 60\%$$

Answers to questions on page 122.

5.3A Often enough to prevent septic conditions or sludge gasification.

5.3B Stop pumping sludge when it becomes thin. Thin sludge can be detected by the sound of the sludge pump, differences in sludge-pumping pressure gauge readings, and by visual observation of the sludge.

5.3C Scum can be kept out of the clarifier effluent by a baffle placed around the inside edge of the overflow weir.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 127.

5.6A Short-circuiting occurs in a clarifier when the flow is not uniform throughout the tank. In this situation the water flows too rapidly in one or more sections of the clarifier to allow sufficient time for settling to occur.

5.6B Short-circuiting is undesirable because where the velocity is too high, particles will not have time to settle. Where the velocity is too low, undesirable septic conditions may develop.

5.6C Short-circuiting may be corrected by installing weir plates or baffles.

5.6D

$$\text{Tank Volume, cu ft} = \frac{\pi}{4} \times (\text{Diameter, ft})^2 \times \text{Depth, ft}$$

$$= (0.785)\ (80\text{ ft})^2 \times 10\text{ ft}$$

$$0.785 \times 6400 \times 10$$

$$= 0.785 \times 64{,}000$$

$$= 50{,}240\text{ cu ft}$$

$$\text{Tank Volume, gal} = 50{,}240\text{ cu ft} \times 7.5\text{ gal/cu ft}$$

$$= 376{,}800\text{ gal}$$

1.

$$\text{Detention Time, hrs} = \frac{\text{Tank Volume, gal} \times 24\text{ hr/day}}{\text{Flow, gal/day}}$$

$$= \frac{376{,}800\text{ gal} \times 24\text{ hr/day}}{4{,}000{,}000\text{ gal/day}}$$

$$= .376800 \times 6$$

$$= 2.2608$$

$$= 2.3\text{ hrs}$$

2.

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow Rate, gpd}}{\text{Length of Weir, ft}}$$

$$= \frac{4{,}000{,}000\text{ gpd}}{3.14 \times 80\text{ ft}}$$

$$= \frac{4{,}000{,}000\text{ gpd}}{251.2\text{ ft}}$$

$$= 15{,}923\text{ gpd/ft}$$

$$\begin{array}{r} 15923. \\ 251.2\overline{)\,4000000.0} \\ \underline{2512} \\ 14880 \\ \underline{12560} \\ 23200 \\ \underline{22608} \\ 5020 \\ \underline{5024} \\ 896\ 0 \\ 753\ 6 \end{array}$$

3. Surface Loading Rate

Calculate Surface Area, sq ft

$$\text{Surface Area, sq ft} = \frac{\pi}{4} \times (\text{Diameter, ft})^2$$

$$= (0.785)\ (80\text{ ft})^2$$

$$= 0.785 \times 6400$$

$$= 5{,}024\text{ sq ft}$$

$$\text{Surface Loading Rate, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{4{,}000{,}000\text{ gpd}}{5{,}024\text{ sq ft}}$$

$$= 800\text{ gpd/sq ft (close enough)}$$

NOTE: The suspended solids concentration of 190 mg/*L* was not needed to solve this problem. Try to determine the information to solve problems and forget the unimportant data.

5.6E Solids Loading

Calculate Solids Applied, lbs/day

$$\text{Solids Applied, lbs/day} = \text{Total Flow, MGD} \times \text{Conc., mg}/L \times 8.34\text{ lbs/gal}$$

$$= (4.0\text{ MGD} + 1.2\text{ MGD}) \times 2700\text{ mg}/L \times 8.34\text{ lbs/gal}$$

$$= 117{,}094\text{ lbs/day}$$

$$\text{Solids Loading, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

$$= \frac{117{,}094\text{ lbs/day}}{5{,}024\text{ sq ft}} \quad \text{(from 5.6D)}$$

$$= 23.3\text{ lbs/day/sq ft}$$

Answers to questions on page 132.

5.6F Secondary clarifiers are needed in secondary treatment plants to remove solids from the secondary process.

5.6G Sludge settling in the secondary clarifier may be returned to the primary clarifier to be settled with the primary sludge, pumped to the beginning of the biological process for recycling, or pumped directly to the sludge-handling facilities.

Answers to questions on page 135.

5.7A Safety items that should be considered when reviewing plans and specifications for clarifiers include:

1. Access to clarifier;
2. Toeboards and nonskid surfaces on catwalks and bridges;
3. Adequate lighting;
4. Safety grates over entrances to launders, channels and effluent pipelines.
5. In a circular clarifier, baffles and valves should be accessible without having to leave a bridge or catwalk; and
6. Guards over moving parts.

5.8A The flotation process is used to remove colloids and emulsions.

5.8B After.

5.8C Colloids— Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

Emulsion — A liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid held in suspension in the other.

5.8D The vacuum flotation process consists of aerating the wastewater and creating a vacuum to pull out the air which will carry the solids to the water surface.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 142 and 143.

5.9A A combined sedimentation-digestion unit consits of a small clarifier constructed over a sludge digester. Treatment units of this type have been designed and constructed to serve small populations.

5.9B Abnormal operating conditions that might be encountered include:

1. Inflows higher than design flows,
2. High solids loadings, and
3. Toxic substances or high or low pH levels.

5.9C Major maintenance items for a combined sedimentation-digestion unit include:

1. Lubricate all equipment in accordance with manufacturers' recommendations;
2. If a tool or object falls into the clarifier, stop rotation and remove tool or object; and
3. If scraper mechanism stops moving, determine cause and remove it before attempting to start mechanism again.

Answers to questions on page 144.

5.10A (1) Settling area, and (2) Sludge digestion area.

5.10B Digested sludge in an Imhoff tank is relatively odorless or has a musty smell, and it is black or very dark in color.

5.10C A fairly level sludge blanket is maintained by reversing the flow at regular intervals.

5.10D Settled material may be forced into the digestion compartment by pushing it through the connecting slot with a squeegee. Dragging a chain on the floor and allowing it to pass through the slot is another method for removing the sludge accumulation.

END OF ANSWERS TO QUESTIONS IN LESSON 3

OBJECTIVE TEST

Chapter 5. SEDIMENTATION AND FLOTATION

Please write your name and the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one answer to each question.

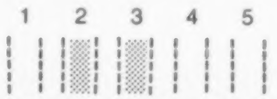
EXAMPLE

The purpose of detaining water in a sedimentation tank is to:

1. Store for future use.
2. Allow solids to settle to the bottom.
3. Allow grease to float to the surface.
4. Hold until trickling filter is ready.
5. Provide chlorine contact time.

To answer this question, you should mark on your answer sheet:

EXAMPLE:



1. Drowning is a constant hazard for operators of wastewater treatment plants.
   1. True
   2. False

2. Primary clarification is a method used to remove settleable solids.
   1. True
   2. False

3. Primary clarifiers are designed to remove colloidal solids.
   1. True
   2. False

4. Flotation and flocculation are both biological treatment processes.
   1. True
   2. False

5. An Imhoff tank treats wastewater by both mechanical and biological treatment processes.
   1. True
   2. False

6. Plant analysis of samples is a reliable method of measuring clarifier efficiency.
   1. True
   2. False

7. Generally, pH is significantly affected by a clarifier.
    1. True
    2. False

8. Influent temperature has little influence on the settling of solids in a primary clarifier.
    1. True
    2. False

9. "Bulking" is a wastewater term that indicates how settleable solids collect and settle out easily.
    1. True
    2. False

10. "Short-circuiting" of a clarifier can cause an operator to be electrocuted.
    1. True
    2. False

11. "Sludge gasification" means pumping air into sludge.
    1. True
    2. False

12. If gases bubble to the surface and floating sludge is noted on the surface of a primary clarifier, this may be a sign of septic conditions.
    1. True
    2. False

13. Floating clumps of sludge indicate good flotation in a clarifier.
    1. True
    2. False

14. A sludge pump that pumps a thick sludge will sound different than when pumping thin sludge.
    1. True
    2. False

15. Samples taken from a clarifier for testing need to be taken only at the effluent or discharge pipes.
    1. True
    2. False

16. Dangerous gases an operator may encounter in and around a treatment plant include
    1. Chlorine.
    2. Fumes from gasoline.
    3. Helium.
    4. Hydrogen sulfide.
    5. Methane.

17. What items should be checked before starting a clarifier?
    1. Lubricate equipment
    2. Remove debris from pipes and tank
    3. Run a clarity test
    4. Sample effluent
    5. Turn off chlorinator

18. What factors influence the settleability of solids in a clarifier?
    1. Detention time
    2. Flow velocity and/or turbulence
    3. Laboratory analyses
    4. Short-circuiting
    5. Temperature

19. If short-circuiting occurs in a clarifier, the operator should
    1. Change pump disconnect fuses.
    2. Check the wiring.
    3. Identify the cause.
    4. Restart the pump.
    5. Try installing baffles.

20. What are "sloughings?"
    1. Material settled out in grit channels
    2. Material washed off trickling filter media
    3. Return activated sludge
    4. Waste activated sludge
    5. Waste sludge troughs

21. Operator errors which can cause primary clarifier equipment or primary process failures include
    1. Improper equipment maintenance and housekeeping.
    2. Inability to properly adjust aeration rates.
    3. Inability to recognize a mechanical-electrical problem.
    4. Insufficient frequency or time for removing sludge.
    5. Insufficient knowledge to properly interpret results of laboratory analyses.

22. Abnormal conditions influencing clarifier performance include
    1. Influent BOD of 195 mg/*L*.
    2. Influent suspended solids of 219 mg/*L*.
    3. Septicity from collection system problems.
    4. Storm flows and hydraulic overloads.
    5. Toxic wastes from industrial spills or dumps.

23. Which of the following is *NOT* an indication of poor clarifier operation?
    1. Floating clumps of sludge on water surface
    2. Loss of solids over effluent weir
    3. Low pH of wastewater and odors
    4. Ninety to ninety-five percent settleable solids removal
    5. Skimmed solids not entering the scum trough

24. An operator can tell if "thin" sludge is being pumped by
    1. Pressure gage readings on the suction and discharge pipes of the pump.
    2. The color of the sludge.
    3. The smell of the sludge.
    4. The sound of the sludge pump.
    5. Visual observation.

25. Skimmed solids may be disposed of by
    1. Burying with material from bar screen.
    2. Flotation.
    3. Incineration.
    4. Pumping to a secondary treatment process.
    5. Pumping to headworks.

26. The maintenance program for a properly operating clarifier should include
    1. Analyzing influent and effluent samples.
    2. Keeping a list of repairs.
    3. Lubricating equipment at regular intervals.
    4. Prompt adjustment or repair when necessary.
    5. Regular inspection.

27. A sludge collector failure may be detected by observing
    1. Broken parts.
    2. Equipment stalling.
    3. Pump not pumping.
    4. Sludge rising to surface.
    5. Thin sludge being pumped.

28. Given the following information regarding a primary sedimentation tank:
    a. Raw sludge pump runs for 10 minutes each hour.
    b. Raw sludge has 7 percent total solids at start of pumping cycle and 5 percent total solids at end of pumping cycle.
    c. Sludge collectors run constantly.
    d. Deep sludge accumulation over entire tank floor.

    Would you make any changes in the operation of this primary sedimentation tank?
    1. No, everything is satisfactory.
    2. Yes, try to decrease the number of sedimentation tanks in service.
    3. Yes, decrease time of sludge collector operating cycle.
    4. Yes, decrease raw sludge pumping cycle.
    5. Yes, increase raw sludge pumping cycle.

29. Given the following information regarding a primary sedimentation tank:
    a. Floating sludge near effluent end of tank.
    b. Raw sludge pump runs for 10 minutes out of each hour.
    c. Raw sludge has 7 percent total solids at start of pumping cycle, 2 percent total solids at end.
    d. Sludge collectors turn on for 30 minutes before pumping begins and shut off when pumping starts.
    e. Moderate sludge accumulations over entire tank floor.

    Would you make any changes in the operation of this primary sedimentation tank?
    1. No, everything is satisfactory.
    2. Yes, decrease raw sludge pumping cycle.
    3. Yes, increase raw sludge pumping cycle.
    4. Yes, decrease time of sludge collector schedule.
    5. Yes, increase time of sludge collector schedule.

30. Secondary or final clarifiers are needed to
    1. Allow septic conditions to develop.
    2. Increase sludge digestion.
    3. Prevent secondary flocculation from occurring.
    4. Provide a home for organisms.
    5. Remove biological solids from wastewater.

31. An Imhoff tank has
    1. A piping system that may allow the direction of flow in the tank to be reversed from one end to the other end.
    2. A separate sludge digestion compartment under the settling area.
    3. Gas vents.
    4. Mechanical sludge scrapers.
    5. Two compartments.

32. Estimate the detention time in a 30,000-gallon sedimentation tank if the flow is 0.3 MGD. Select the closest answer.
    1. 1.5 hr
    2. 2.0 hr
    3. 2.4 hr
    4. 3.3 hr
    5. 4.2 hr

33. Estimate the detention time in a sedimentation tank 100 ft long, 30 ft wide, and 12 ft deep, if the flow is 3.0 MGD. Select the closest answer.
    1. 2.2 hr
    2. 2.6 hr
    3. 2.9 hr
    4. 3.4 hr
    5. 3.8 hr

END OF OBJECTIVE TEST

CLEANWATER, U.S.A.

WATER POLLUTION CONTROL PLANT

MONTHLY RECORD : __________ 19____

OPERATOR: ______________

				RAW WASTEWATER						EFFLUENT					DIGESTION					REMARKS
DATE	DAY	WEATHER	FLOW MGD	TEMP.	pH	SETT. SOLIDS	BOD	SUSP. SOLIDS	GRIT – YD.^{3}	pH	BOD	SUSP. SOLIDS	DO	CL$_2$ RES.	RAW SLUDGE GAL / DAY	SCUM GAL / DAY	% CO$_2$	GAS PROD. FT^3/ DAY	MIXING – HRS.	
1	M	FAIR	1.200	70	7.3	8	190	208	1.0	7.2	118	110	1.0	2.1	4750	100	32	10400	4	
2	T	"	1.051	69	7.2	10	205	218	1.0	7.1	128	108	1.1	2.4	4108	110	32	10900	–	
3	W	"	1.120	69	7.3	11	220	222	1.5	7.1	154	111	0.9	3.0	4302	90	33	10800	8	
4	T	"	0.987	70	7.1	9	184	201	1.0	7.0	130	97	1.2	1.8	3810	120	33	11200	8	Sludge to #1 Bed – 16,000 Gal.
5	F	CL.	1.008	68	7.0	7	232	248	1.0	7.0	140	112	0.7	1.9	4005	115	34	10600	8	
6	S	"	1.102	68	7.2	9	211	210	0.75	7.1	138	100	0.8	2.1	4190	120	32	11000	4	
7	S	FAIR	0.974	69	7.3	8	199	215	0.75	7.1	140	101	0.9	2.0	3915	110	32	10800	4	
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29																				
30																				
31																				
MAX.																				
MIN.																				
AVG.			1.016	69	7.1	9	195	210	1.0	7.1	135	106	0.9	2.0	4154	100	33	10810	5	

SUMMARY DATA

% REMOVAL	BOD	S S
INF. – EFF.	30	49

SLUDGE DATA

% SOLIDS – AVG.	4.8
LBS. DRY SOLIDS / DAY	1663
% VOL. SOLIDS – AVG.	76
LBS. VOL. SOLIDS / DAY	1264
LBS. VOL. SOL. /1000 FT.^{3}/DAY	25.3
GAL. SLUDGE TO BEDS	48,000
CU. YDS. CAKE REMOVED	22
FT.^{3} GAS / LB. VOL. SOLIDS	8.5
FT.^{3} GAS / MG. FLOW	10,640
CU. YDS. GRIT / MG. FLOW	1.0

COST DATA

MAN DAYS 44 PAYROLL	$ 1250 –
POWER PURCHASED	250 –
OTHER UTILITIES (GAS ETC.)	60 –
GASOLINE, OIL, GREASE	30 –
CHEMICALS & SUPPLIES	60 –
MAINTENANCE	130 –
VEHICLE COSTS	70 –
OTHER	20 –
TOTAL	$ 1870 –
OPERATING COST / MG.	$ 59.37
OPERATING COST / CAPITA / MG	$ 0.19

FLOW METER:
LAST 445237
1st 413749
TOTAL 31.488 MG

ELECTRIC METER:
LAST 5029
1st 4821
MULT 80 x 208 = 16,640 KWH

RAW SLUDGE:
LAST 828588
1st 699814
STROKES—SCUM 3100
TOTAL 128,774 x 1.0 = 128,774 GALS.

GAS METER:
LAST 718406
1st 383296
TOTAL 335,110 FT^3

CHAPTER 6

TRICKLING FILTERS

by

Larry Bristow

TABLE OF CONTENTS

Chapter 6. Trickling Filters

Page

OBJECTIVES 156

GLOSSARY 156

LESSON 1

6.0 How a Trickling Filter Works 159

6.00 Description of a Trickling Filter 159

6.01 Principles of Treatment Process 159

6.02 Principles of Operation 165

6.1 Classification of Filters 167

6.10 General 167

6.11 Standard-Rate Filters 167

6.12 High-Rate Filters 167

6.13 Roughing Filters 167

6.14 Filter Staging 167

6.2 Starting, Operating and Shutting Down a Filter 169

6.20 Pre-Start 169

6.21 Placing Filter in Service 169

6.22 Daily Operation 170

6.23 Shutdown of a Filter 170

6.3 Sampling and Analysis 171

6.30 Important Considerations 171

6.31 Typical Trickling Filter Plant Lab Results 171

6.32 Response to Poor Trickling-Filter Performance 171

LESSON 2

6.4 Operational Strategy 173

6.40 Daily Operating Procedures 173

6.41 Response to Abnormal Conditions 174

6.410 Ponding 174

6.411 Odors 176

    6.412 Filter Flies 176
    6.413 Cold Weather Problems 177
    6.414 Plant Inflow 177
    6.415 Operational Problems with Upstream or Downstream Treatment Processes 179
  6.42 Troubleshooting 179
6.5 Maintenance 181
  6.50 Bearings and Seals 181
  6.51 Distributor Arms 181
  6.52 Fixed Nozzles 181
  6.53 Underdrains 183
  6.54 Recirculation Pumps 183
6.6 Safety 183

LESSON 3

6.7 Loading Criteria 184
  6.70 Typical Loading Rates 184
  6.71 Computing Hydraulic Loading 184
  6.72 Computing Organic (BOD) Loading 185
  6.73 Typical Loading Rates (Metric) 185
  6.74 Computing Hydraulic Loading (Metric) 185
  6.75 Computing Organic (BOD) Loading (Metric) 186
6.8 Trickling Filter/Solids Contact (TF/SC) Process 186
6.9 Review of Plans and Specifications 186
6.10 Arithmetic Assignment 187
6.11 Additional Reading on Trickling Filters 188
6.12 Metric Calculations 188

OBJECTIVES

Chapter 6. TRICKLING FILTERS

Following completion of Chapter 6, you should be able to do the following:

1. Explain the principles of the trickling-filter treatment process and the operation of the process,
2. Inspect a new trickling filter for proper installation,
3. Place a new filter into service,
4. Schedule and safely conduct operation and maintenance duties,
5. Sample influent and effluent, interpret lab results, and make appropriate adjustments in treatment process,
6. Recognize factors that indicate a trickling filter is not performing properly, identify the source of the problem, and take corrective action,
7. Develop an operating strategy for a trickling filter,
8. Conduct your duties in a safe fashion,
9. Identify the different types of trickling filters,
10. Determine hydraulic and organic loadings on a trickling filter, and
11. Keep records for a trickling-filter plant.

GLOSSARY

Chapter 6. TRICKLING FILTERS

AEROBIC PROCESS (AIR-O-bick) AEROBIC PROCESS

A waste treatment process conducted under aerobic (in the presence of "free" or dissolved oxygen) conditions.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" or dissolved oxygen is *NOT* present in the aquatic environment.

BIOMASS (BUY-o-MASS) BIOMASS

A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris. This mass may be formed for, or function as, protection against predators and storage of food supplies. See ZOOGLEAL FILM.

COLLOIDS (KOL-loids) COLLOIDS

Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

DISTRIBUTOR DISTRIBUTOR

The rotating mechanism that distributes the wastewater evenly over the surface of a trickling filter or other process unit. Also see FIXED SPRAY NOZZLE.

FIXED SPRAY NOZZLE FIXED SPRAY NOZZLE

Cone-shaped spray nozzle used to distribute wastewater over the filter media, similar to a lawn sprinkling system. A deflector or steel ball is mounted within the cone to spread the flow of wastewater through the cone, thus causing a spraying action. Also see DISTRIBUTOR.

FORCE MAIN FORCE MAIN

A pipe that conveys wastewater under pressure from the discharge side of a pump to a point of gravity flow.

HUMUS SLUDGE HUMUS SLUDGE

The sloughed particles of biomass from trickling filter media that are removed from the water being treated in secondary clarifiers.

LOADING LOADING

Quantity of material applied to a device at one time.

MASKING AGENTS MASKING AGENTS

Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.

MICROORGANISMS (micro-ORGAN-is-zums) MICROORGANISMS

Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

NITRIFICATION (NYE-tri-fi-KAY-shun) NITRIFICATION

A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

ORIFICE (OR-uh-fiss) ORIFICE

An opening in a plate, wall, or partition. In a trickling-filter distributor, the wastewater passes through an orifice to the surface of the filter media. An orifice flange set in a pipe consists of a slot or hole smaller than the pipe diameter. The difference in pressure in the pipe above and below the orifice may be related to flow in the pipe.

PARALLEL OPERATION PARALLEL OPERATION

When wastewater being treated is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit. Also see SERIES OPERATION.

PHYSICAL WASTE TREATMENT PROCESS PHYSICAL WASTE TREATMENT PROCESS

Physical waste treatment processes include use of racks, screens, comminutors, and clarifiers (sedimentation and flotation). Chemical or biological reactions are not an important part of a physical treatment process.

PONDING PONDING

A condition occurring on trickling filters when the hollow spaces (voids) become plugged to the extent that water passage through the filter is inadequate. Ponding may be the result of excessive slime growths, trash, or media breakdown.

PROTOZOA (pro-toe-ZOE-ah) PROTOZOA

A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.

RECIRCULATION RECIRCULATION

The return of part of the effluent from a treatment process to the incoming flow.

SECONDARY TREATMENT SECONDARY TREATMENT

A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

SERIES OPERATION SERIES OPERATION

When wastewater being treated flows through one treatment unit and then flows through another similar treatment unit. Also see PARALLEL OPERATION.

SHOCK LOAD SHOCK LOAD

The arrival at a plant of waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and sloughing off of the growth or slime on the trickling-filter media. Organic or hydraulic overloads also can cause a shock load.

TRICKLING FILTER TRICKLING FILTER

A treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water being treated.

TRICKLING-FILTER MEDIA TRICKLING-FILTER MEDIA

Rocks or other durable materials that make up the body of the filter. Synthetic (manufactured) media have been used successfully.

TWO-STAGE FILTERS TWO-STAGE FILTERS

Two filters are used. Effluent from the first filter goes to the second filter, either directly or after passing through a clarifier.

ZOOGLEAL FILM (ZOE-glee-al) ZOOGLEAL FILM

A complex population of organisms that form a "slime growth" on the trickling-filter media and break down the organic matter in wastewater. These slimes consist of living organisms feeding on the wastes in wastewater, dead organisms, silt, and other debris. "Slime growth" is a more common word.

CHAPTER 6. TRICKLING FILTERS

(Lesson 1 of 3 Lessons)

6.0 HOW A TRICKLING FILTER WORKS

6.00 Description of a Trickling Filter

In the initial chapters of this course, you have learned about physical methods of wastewater treatment. In general, these techniques (processes) consist of the screening of large particles, settling of heavy material, and floating of light material by preliminary and primary treatment units (screen, grit channel, clarifier). Although primary treatment is very efficient for removing settleable solids, it is not capable of removing lighter suspended solids or dissolved solids which may exert a strong oxygen demand on the receiving waters.

In order to remove the very small suspended solids (colloids) and dissolved solids, most waste treatment plants now being built include *SECONDARY TREATMENT*.[1] This additional process increases overall plant removal of suspended solids and BOD to 90 percent or more. The two most common secondary treatment processes are trickling filters and activated sludge. This chapter will deal with *TRICKLING FILTERS*.[2]

SECONDARY TREATMENT PROCESS
TRICKLING FILTER

Figures 6.1 and 6.2 show where a trickling filter usually is located in a plant.

Most trickling filters are large-diameter, shallow, cylindrical structures filled with stone and having an overhead distributor. (See Fig. 6.3 and Table 6.1.) Many variations of this design have been built. When natural media (stones) are used, the trickling filter is usually cylindrical with a shallow bed; when synthetic media (plastics) are used, the filter could be cylindrical or rectangular with a much deeper bed. Some recent designs have used redwood packing and a deep bed. Square or rectangular filters have been constructed with fixed sprinklers for wastewater distribution. Another type of filter is called the "rotating biological contactor" and is discussed in detail in Chapter 7. This contactor treats the wastewater using methods similar to a trickling filter except instead of applying water over the media, the media are rotated through the wastewater being treated. The structures for trickling filters or rotating biological contactors may be covered for odor-control purposes, or to prevent freezing in some areas.

6.01 Principles of Treatment Process

Trickling filters, biological oxidation beds, and rotating biological contactors consist of three basic parts:

1. The media (and retaining structure),
2. The underdrain system, and
3. The distribution system.

The media provide a large surface area upon which a biological slime growth develops. This slime growth, sometimes called a *ZOOGLEAL FILM*,[3] contains the living organisms that break down the organic material. The media may be rock, slag, coal, bricks, redwood blocks, molded plastic (Fig. 6.4), or any other sound, durable material. The media should be of such sizes and stacked in such a fashion to provide empty spaces (voids) for air to ventilate the filter and keep conditions aerobic. For rock, the size will usually be from about two inches to four inches (5 to 10 cm). Although actual size is not too critical, it is important that the media be uniform in size to permit adequate ventilation. The media depth ranges from about three to eight feet (1 to 2.5 meters) for trickling filters.

The underdrain system of a trickling filter has a sloping bottom. This leads to a center channel which collects the filter effluent. The underdrain system also supports the media and permits air flow. Common materials and methods for constructing underdrain systems include the use of spaced redwood stringers and of prefabricated blocks constructed of concrete, vitrified clay, or other suitable material.

The distribution system, in the vast majority of cases, is a rotary-type distributor which consists of two or more horizontal pipes supported a few inches above the filter media by a central column. The wastewater is fed from the column through the horizontal pipes and is distributed over the media through orifices located along one side of each of these pipes (or arms). Rotation of the arms is due either to the rotating water-sprinkler reaction from wastewater flowing out the orifices ("jet like") or by some mechanical means. The distributors are equipped with mechanical-type seals at the center column to prevent leakage and protect the bearings, guy- or stay rods for seasonal adjustment of the distributor arms to maintain an

---

[1] *Secondary Treatment. A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.*

[2] *Trickling Filters. A treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water being treated. Trickling filters are sometimes called biofilters, accelo filters or aerofilters, depending on the recirculation pattern.*

[3] *Zoogleal Film (ZOE-glee-al). A complex population of organisms that form a "slime growth" on the trickling-filter media and break down the organic matter in wastewater. These slimes consist of living organisms feeding on the wastes in wastewater, dead organisms, silt, and other debris. "Slime growth" is a more common word.*

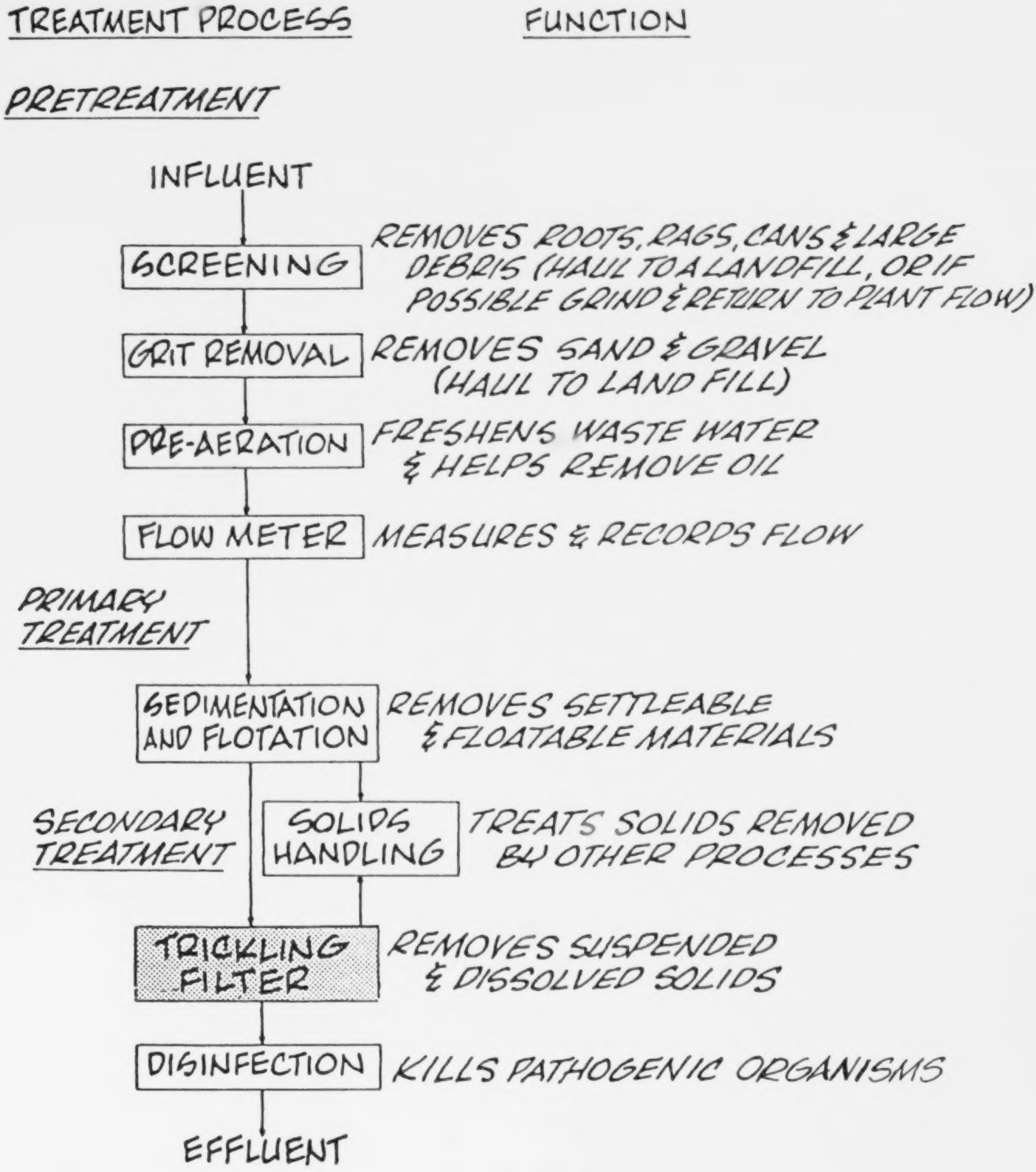

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
TRICKLING FILTER
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
EFFLUENT

Fig. 6.1 Flow diagram of treatment plant

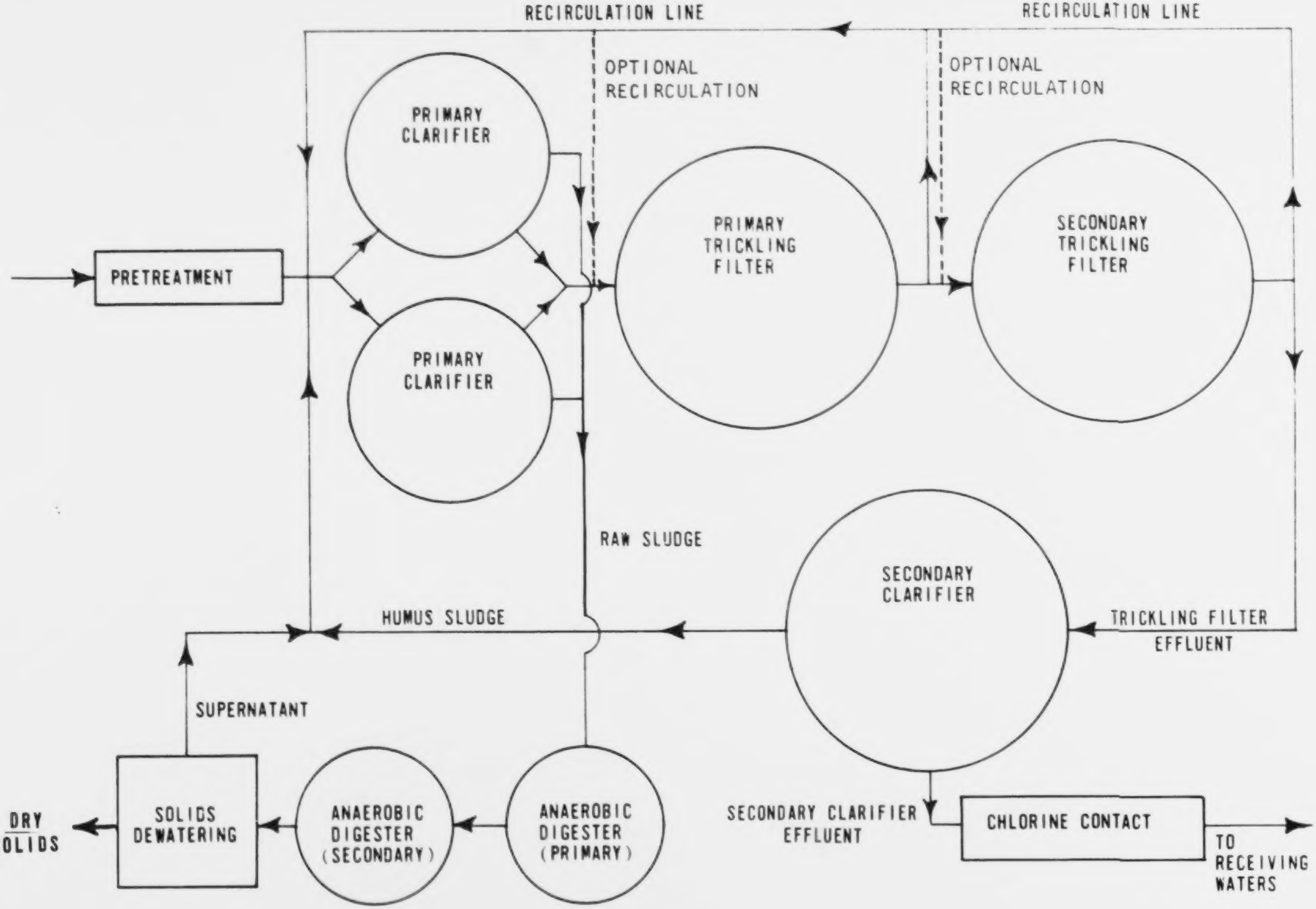

RECIRCULATION LINE
RECIRCULATION LINE
OPTIONAL RECIRCULATION
OPTIONAL RECIRCULATION
PRETREATMENT
PRIMARY CLARIFIER
PRIMARY CLARIFIER
PRIMARY TRICKLING FILTER
SECONDARY TRICKLING FILTER
RAW SLUDGE
SECONDARY CLARIFIER
HUMUS SLUDGE
TRICKLING FILTER EFFLUENT
SUPERNATANT
DRY SOLIDS
SOLIDS DEWATERING
ANAEROBIC DIGESTER (SECONDARY)
ANAEROBIC DIGESTER (PRIMARY)
SECONDARY CLARIFIER EFFLUENT
CHLORINE CONTACT
TO RECEIVING WATERS

Fig. 6.2 Plan of typical trickling filter plant

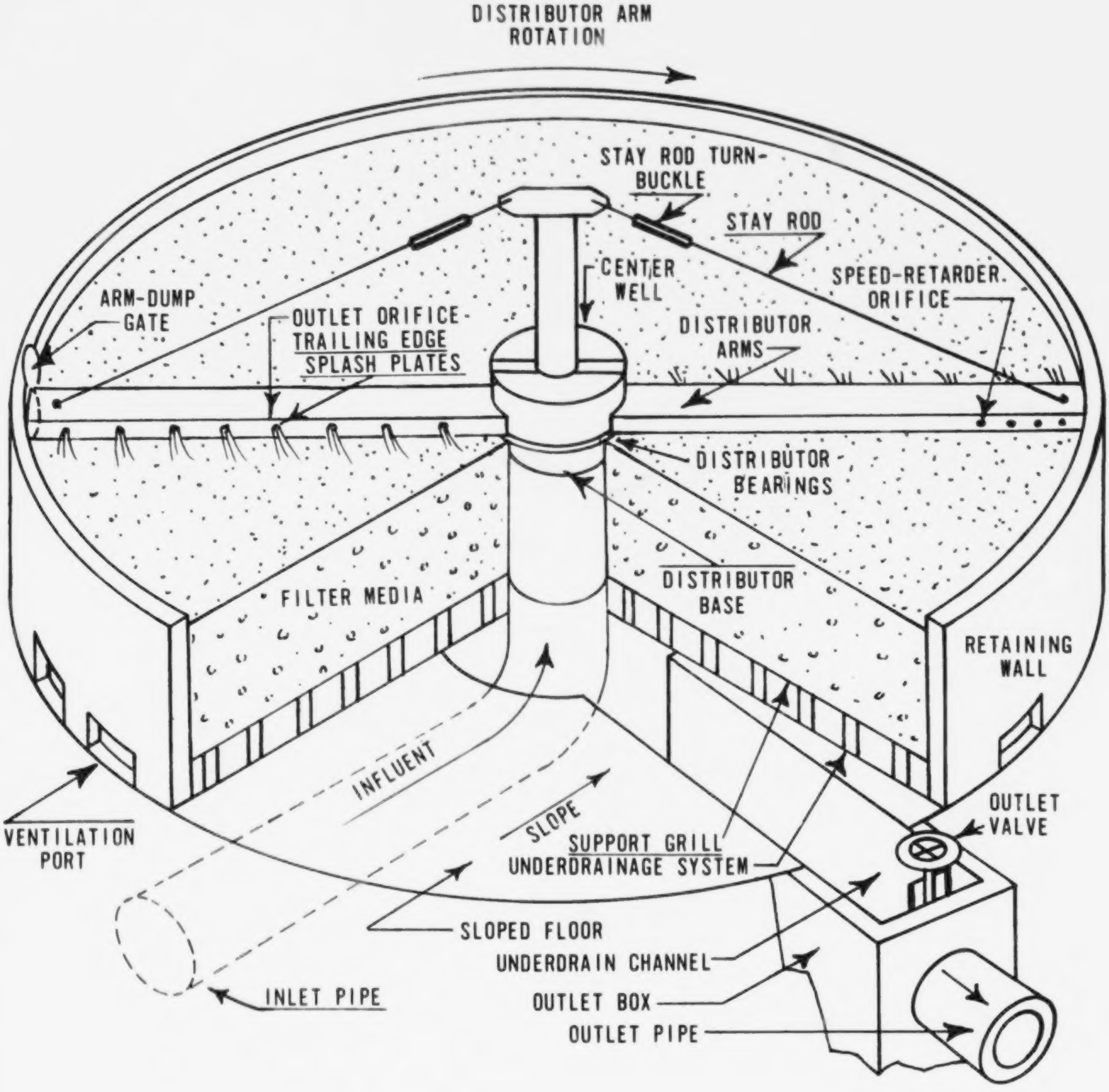

DISTRIBUTOR ARM ROTATION
STAY ROD TURN-BUCKLE
STAY ROD
CENTER WELL
SPEED-RETARDER ORIFICE
ARM-DUMP GATE
OUTLET ORIFICE
TRAILING EDGE SPLASH PLATES
DISTRIBUTOR ARMS
DISTRIBUTOR BEARINGS
FILTER MEDIA
DISTRIBUTOR BASE
RETAINING WALL
INFLUENT
SLOPE
OUTLET VALVE
VENTILATION PORT
SUPPORT GRILL
UNDERDRAINAGE SYSTEM
SLOPED FLOOR
UNDERDRAIN CHANNEL
INLET PIPE
OUTLET BOX
OUTLET PIPE

Fig. 6.3 Trickling filter

TABLE 6.1 PURPOSE OF TRICKLING FILTER PARTS

Part	Purpose
1. Inlet Pipe	Conveys wastewater to be treated to trickling filter.
2. Distributor Base	Supports rotating distributor arms.
3. Distributor Bearings	Allow distributor arms to rotate.
4. Distributor Arm	Conveys wastewater to outlet orifices located along arms.
5. Outlet Orifice	Controls flow to filter media. Adjustable to provide even distribution of wastewater to each square foot of filter media.
6. Speed-retarder Orifice	Regulates speed of distributor arms.
7. Splash Plate	Distributes flow from orifices evenly over filter media.
8. Arm Dump-gate	Drains distributor arm and controls filter flies along filter retaining wall. Also used for flushing distributor arm to remove accumulated debris which might block outlet orifices.
9. Filter Media	Provide a large surface area upon which the biological slime growth develops.
10. Support Grill	Keeps filter media in place and out of underdrainage system.
11. Underdrain System	Collects treated wastewater from under filter media and conveys it to underdrain channel. Also permits air flow through media.
12. Underdrain Channel	Drains filter effluent to outlet box.
13. Outlet Box	Collects filter effluent before it flows to next process.
14. Outlet Valve	Regulates flow of filter effluent from outlet box into outlet pipe. Closed when filter is to be flooded.
15. Outlet Pipe	Conveys filter effluent to next treatment process.
16. Retaining Wall	Holds filter media in place.
17. Ventilation Port	Allows air to flow through media.
18. Stay Rod	Supports distributor arm.
19. Turnbuckle on Stay Rod	Permits adjusting and leveling of distributor arm in order to produce even distribution of wastewater over the media.
20. Center Well	Provides for higher water head to maintain equal flow to distributor arms. Usually a head of 18 to 24 inches (45 to 60 cm) is maintained on the orifices.
21. Splitter Box	Divides flow to trickling filters, for recirculation or to secondary clarifiers.
22. Recirculation Pump	Returns or recirculates flows to trickling filters.

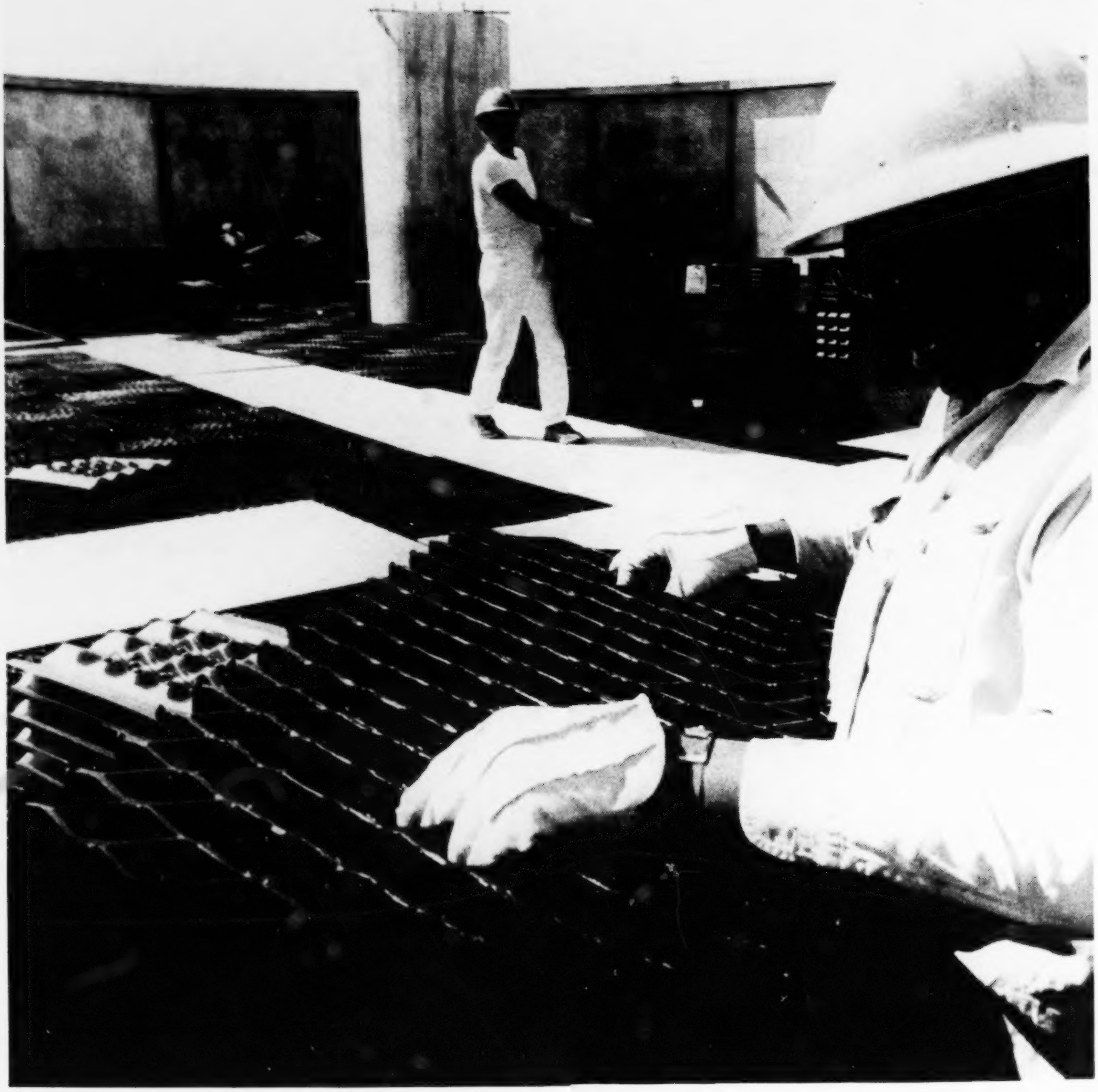


Fig. 6.4 Installation of synthetic media in trickling filter

(Courtesy of The Dow Chemical Company)

even distribution of wastewater over the media, and quick-opening or arm dump-gates at the end of each arm to permit easy flushing.

The fixed-nozzle distribution system is not as common as the rotary type. The nozzles are located on the surface of the filter like a lawn sprinkler system. Each fixed-nozzle consists of a circular orifice with an inverted cone-shaped deflector mounted above the center. The deflector breaks the flow into a spray. Some types have a steel ball in the inverted cone. (See Fig. 6.5.) The fixed-nozzle system requires an elaborate piping system to insure even distribution of the wastewater. The nozzles extend six to twelve inches (15 to 30 cm) above the media and are shaped so that an overlapping spray pattern exists at the start of dosing when the head in the dosing tank is the greatest. The pattern is carefully worked out to provide a relatively even distribution of the wastewater.

Flow is usually intermittent and is controlled by automatic siphons which regulate the flow from dosing tanks. (See Fig. 6.5.) Dosing tanks and siphons should be constructed to facilitate cleaning and reduce problems caused by corrosion. Attempt to record the time required to fill and discharge the dosing chamber. If this time becomes shorter, this could indicate that grease and solids are accumulating in the siphon and pipes and should be removed.

6.02 Principles and Operation

The maintenance of a good growth of organisms on the filter media is crucial to successful operation.

BACTERIA
PROTOZOA
OTHER
ORGANISMS

The term "filter" is rather misleading because it indicates that solids are separated from liquid by a straining action. This is not the case. Passage of wastewater through the filter causes the development of a gelatinous coating of bacteria, protozoa, and other organisms on the media. This growth of organisms absorbs and utilizes much of the suspended, colloidal, and dissolved organic matter from the wastewater as it passes over the growth in a rather thin film. Part of this material is utilized as food for production of new cells, while another portion is oxidized to carbon dioxide and water. Partially decomposed organic matter together with excess and dead film is continuously or periodically washed (sloughed) off and passes from the filter with the effluent.

For the oxidation (decomposition) processes to be carried out, the biological film requires a continuous supply of dissolved oxygen which may be absorbed from the air circulating through the filter voids (spaces between the rocks or other media). Adequate ventilation of the filter must be provided; therefore the voids in the filter media must be kept open. Ventilation may be by either natural ventilation or by a forced air ventilation system. Clogged voids can create operational problems including ponding and reduction in overall filter efficiency.

A method of increasing the efficiency of trickling filters is to add recirculation. Recirculation is a process in which filter effluent is recycled and brought into contact with the biological film more than once. Recycling of filter effluent increases the contact time with the biological film and helps to seed the lower portions of the filter with active organisms. Due to the increased flow rate per unit of area, higher velocities occur which tend to cause more continuous and uniform sloughing of excess or aged growths. Uniform and continuous sloughing of growths is important because this provides a more aggressive surface of new growths to treat the wastewater. Sloughing of growths prevents ponding and improves ventilation through the filter. Increased hydraulic loadings also decreases the opportunity for snail and filter fly breeding. The thickness of the biological growth has been observed to be directly related to the organic strength of the wastewater (the higher the BOD, the thicker the layers of organisms). By the use of recirculation, the strength of wastewater applied to the filter can be diluted, thus helping to prevent excessive build-up of growths.

Recirculation may be constant or intermittent and at a steady or fluctuating rate. Sometimes recirculation (recycling) is practiced only during periods of low flow to keep rotary distributors in motion, to prevent drying of the filter growths, or to prevent freezing. Recirculation in proportion to flow may be utilized to reduce the strength of the wastewater applied to the filter, while steady recirculation tends to even out the highs and lows of organic loading. Steady recirculation, however, requires the use of more energy.

Almost any organic waste which can be successfully treated by other aerobic biological processes can be treated on trickling filters. This includes, in addition to domestic wastewater, such wastewaters as might come from food processing, textile, carbonated beverage, dairy and fermentation industries, and certain pharmaceutical processes. Industrial wastewaters which cannot be treated are those which contain excessive concentrations of toxic materials such as pesticide residues, heavy metals, and highly acidic or alkaline wastes.

For maximum efficiency, the slime growths on the filter media should be kept fairly aerobic. This can be accomplished by proper design of the wastewater collection system, proper operation of primary clarifiers, or by pretreatment of the wastewater by aeration or addition of recycled filter effluent. The air supply to the slimes may be improved by increased air or wastewater recirculation. The thin slime growth may be aerobic on the surface, but anaerobic next to the media. A trickling filter media of rock or slag can accumulate slimes only on the outside surface, but manufactured media provide considerably more surface area per unit of dead space.

The temperatures of the wastewater and of the climate also affect filter operation, with temperature of the wastewater being the more important. Of course, temperature of the wastewater will vary with the weather. Within limits, activity of the organisms increases as the temperature rises. Therefore, higher loadings and greater efficiency are possible in warmer climates if aerobic conditions can be reasonably maintained in the filter.

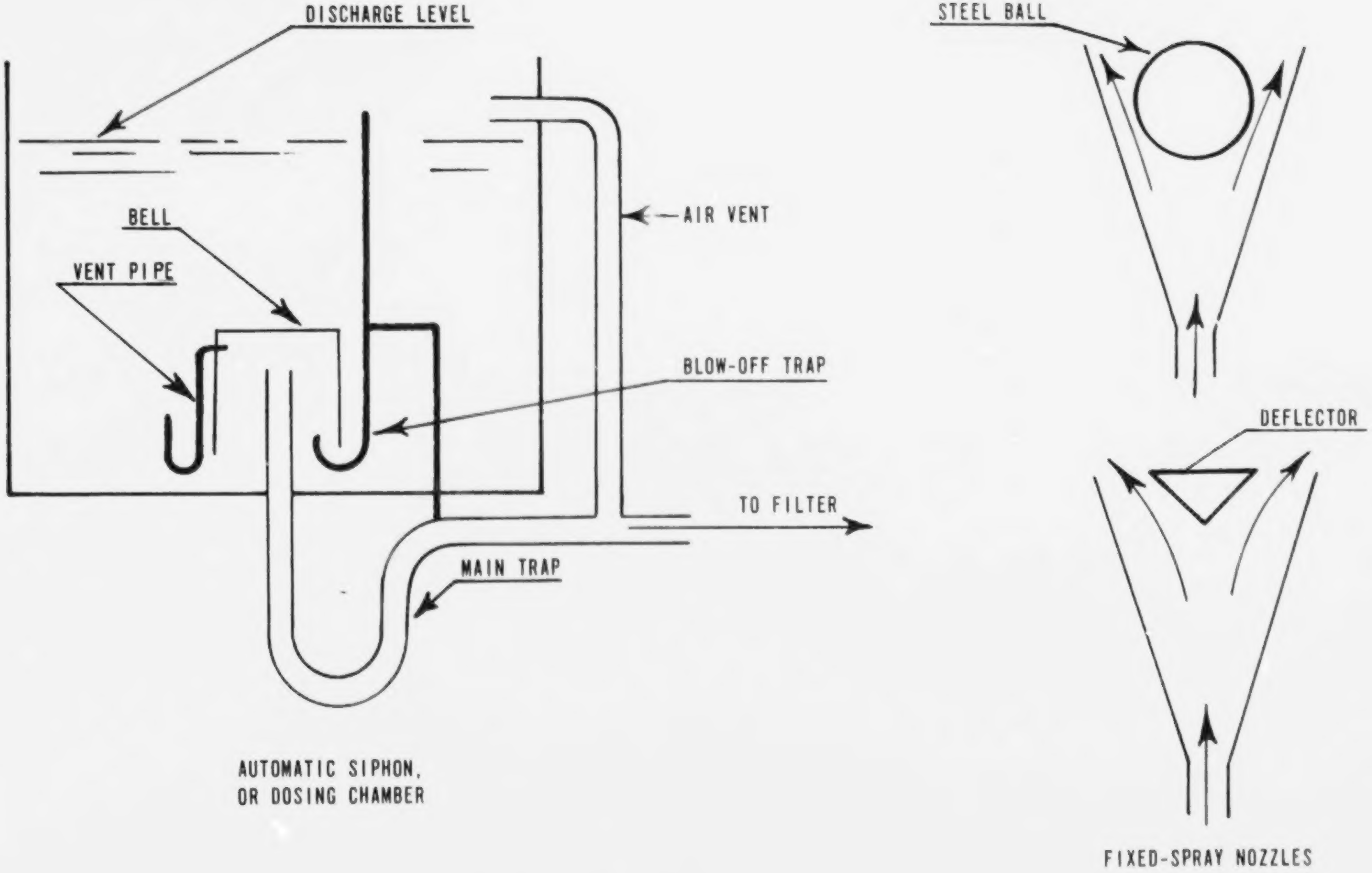

DISCHARGE LEVEL
STEEL BALL
BELL
AIR VENT
VENT PIPE
BLOW-OFF TRAP
DEFLECTOR
TO FILTER
MAIN TRAP
AUTOMATIC SIPHON, OR DOSING CHAMBER
FIXED-SPRAY NOZZLES

Fig. 6.5 Siphon and nozzle details for fixed-spray filters

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 188.

6.0A Primary treatment is effective in removing (a) ______ ______ and (b) ______, but not nearly as effective in removing (c) ______.

6.0B What is the purpose of "secondary treatment"?

6.0C How does the trickling-filter process work?

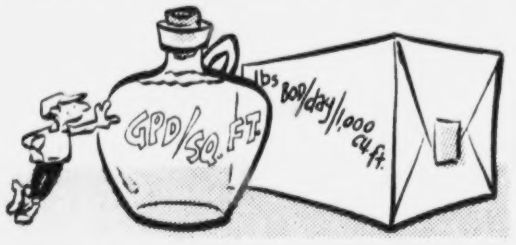
6.0D What causes the distributor arms or pipes to rotate on a trickling filter?

6.0E How does recirculation increase the efficiency of a trickling filter?

6.1 CLASSIFICATION OF FILTERS

6.10 General

Depending upon the hydraulic and organic loadings applied, filters are classified as standard-rate, high-rate, or roughing filters. Further designations such as single-stage, two-stage, and series or parallel are used to indicate the flow pattern of the plant. The hydraulic loading applied to a filter is the total volume of liquid, including recirculation, expressed as gallons per day per square foot of filter surface area (gpd/sq ft). The organic loading is expressed as the pounds of BOD applied per day per 1,000 cubic feet of filter media (lbs BOD/day/1000 cu ft). Where recirculation is used, an additional organic loading will be placed on the filter; however, this added loading is omitted in most calculations because it was included in the influent load. Procedures for calculating the hydraulic and organic loadings are given in Section 6.7, "Loading Criteria."


GPD/SQ. FT.
lbs BOD/day/1,000 cu.ft.

6.11 Standard-Rate Filters

The standard-rate filter is operated with a hydraulic loading range of 25 to 100 gals/day/sq ft (1 to 4 MGD/acre), and an organic BOD loading of 5 to 25 lbs/day/1000 cu ft (200 to 1000 lbs/day/ac ft). The filter media is usually rock with a depth of 6 to 8 feet, with application to the filter by a rotating distributor. Many are equipped to provide some recirculation during low flow periods.

The filter growth is often heavy and, in addition to the bacteria and *PROTOZOA*,[4] many types of worms, snails, and insect larvae can be found. The growth usually sloughs off at intervals, noticeably in spring and fall. The effluent from a standard-rate filter treating municipal wastewater is usually quite stable with BODs as low as 20 to 25 mg/*L*.

6.12 High-Rate Filters

High-rate filters were the result of trying to reduce costs associated with standard-rate filters and attempting to treat increased wasteloads with the same facility. Studies indicated that essentially the same BOD reductions could be obtained at the higher design loadings.

High-rate filters usually have rock media with a depth of 3 to 5 feet. Recommended loadings range from 100 to 1000 gal/day/sq ft (4 to 40 MGD/ac) and 25 to 300 lbs BOD/day/1000 cu ft (1000 to 13,000 lbs/day/ac ft). These filters are designed to receive wastewater continually, and practically all high-rate installations utilize recirculation. Loadings may be higher for synthetic media.

Due to the heavy flow of wastewater over the media, more uniform sloughing of the filter growths occurs from high-rate filters. This sloughed material is somewhat lighter than from a standard-rate unit and therefore more difficult to settle. Effluents with BODs as low as 20 to 50 mg/*L* are sometimes produced by high-rate plants treating municipal wastewater.

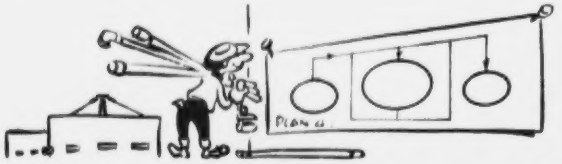
6.13 Roughing Filters

A roughing filter is actually a high-rate filter receiving a very high organic loading. Any filter receiving an organic loading of over 300 lbs of BOD/day/1000 cu ft of media is considered to be in this class. This type of filter is used primarily to reduce the organic load on subsequent oxidation processes such as a second-stage filter or activated-sludge process. Many times they are used in plants which receive strong organic industrial wastes. They are also used where an intermediate (50-70 percent BOD removal) degree of treatment is satisfactory.

Operation of the filter is basically the same as for the high-rate filters with recirculation. *OVERALL* BOD reductions are much lower, but reductions *PER UNIT VOLUME OF FILTER MEDIA* are greater.

6.14 Filter Staging

Fig. 6.6 shows various filter and clarifier layouts. The decision as to the number of filters (or stages) required is one of design rather than operation. In general, however, at smaller plants where the flow is fairly low, the strength of the raw wastewater is average, and effluent quality requirements are not too strict, a single-stage plant (one filter) is often sufficient and most economical. In slightly overloaded plants, the addition of some recirculation capability can sometimes improve the effluent quality enough to meet receiving water standards and NPDES permit requirements without the necessity of adding more stages.



In two-stage filter plants, two filters are operated in series. Sometimes a secondary clarifier is installed between the two filters. Recirculation is almost universally practiced at two-stage plants with many different arrangements being possible. Choice of recirculation scheme used is based on consideration of which arrangement produces the best effluent under the particular conditions of wastewater strength and other characteristics. (See Fig. 6.6)

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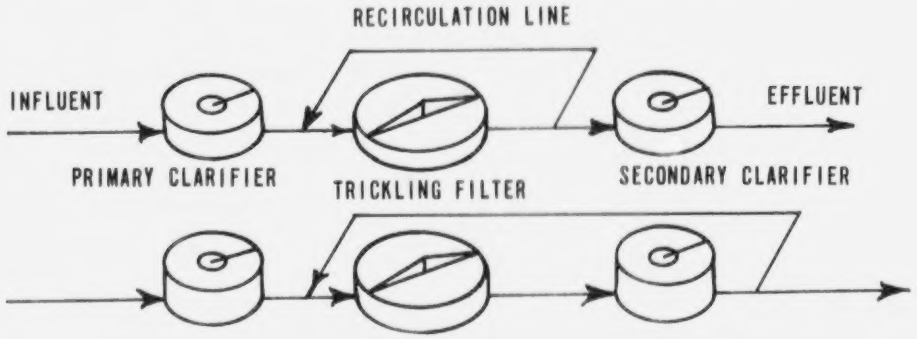
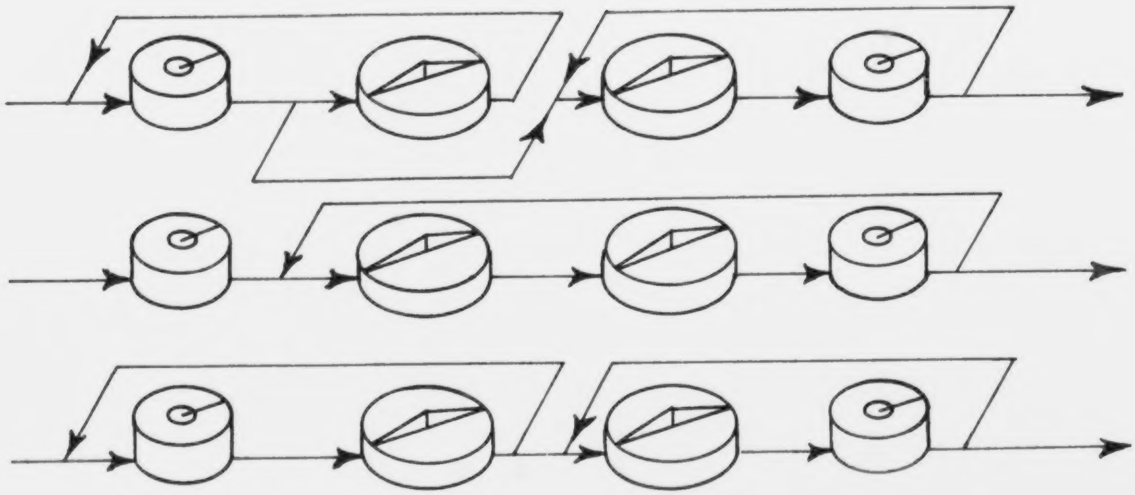
[4] *Protozoa (pro-toe-ZOE-ah). A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.*


RECIRCULATION LINE
INFLUENT
EFFLUENT
PRIMARY CLARIFIER
TRICKLING FILTER
SECONDARY CLARIFIER

Typical Single-Stage Recirculation Patterns



Typical Two-Stage Recirculation Patterns

Fig. 6.6 Trickling filter recirculation patterns

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 188.

6.1A What are the three general classifications of trickling filters?

6.1B What are the principal differences between standard-rate and high-rate filters?

6.2 STARTING, OPERATING AND SHUTTING DOWN A FILTER

6.20 Pre-Start[5]

A new plant is seldom started up without some unexpected, frustrating problems. Some careful inspecting ahead of time can prevent many of these situations.

If at all possible, you should arrange to be present when your new equipment is serviced. You should see that the correct oil is used in all oil reservoirs. Many contractors will put motor oil in everything and consider it serviced. For future reference, record the amount and type of oil each reservoir holds.

After the oil has been installed in a distributor, check the arms for even adjustment and level. Rotate the unit by hand and observe for smooth turning. Any vibration or roughness should be corrected before putting the unit in service.

If the distributor has adjustable orifices, get the erection sheet and a rule and check out the orifice settings. File the erection sheet for future reference.

In a trickling filter plant with fixed-spray nozzles, each nozzle should be checked to insure that it is free of foreign objects.

In order to prevent damage to pumps, crawl into the underdrain system of the filter and remove any debris (rocks, pieces of wood, and other debris). Check painted surfaces for damaged areas. Touch these up before they get wet to prevent corrosion and further damage. A few nicks and scratches in a distributor arm can seriously affect the life of the original protective coatings.

Check all valves in the system for smooth operation. On sliding-gate valves, see that the gates seat properly. There are adjustable wedges and stops on this type of valve. With the valve adjusted, set the lock nut on the stem to prevent jamming or closing the gate too tightly. These small precautions will yield years of trouble-free valve operation.

In addition to the general items covered in this section, you should be certain that the correct manufacturer's manual has been furnished for each piece of equipment. Read each manual carefully and follow the given recommendations. Obtain the oils and greases recommended; or, if you buy from one oil company, have their representative furnish you a *WRITTEN LIST* of the company's products that are equivalent to those recommended by the equipment manufacturer.

6.21 Placing Filter in Service

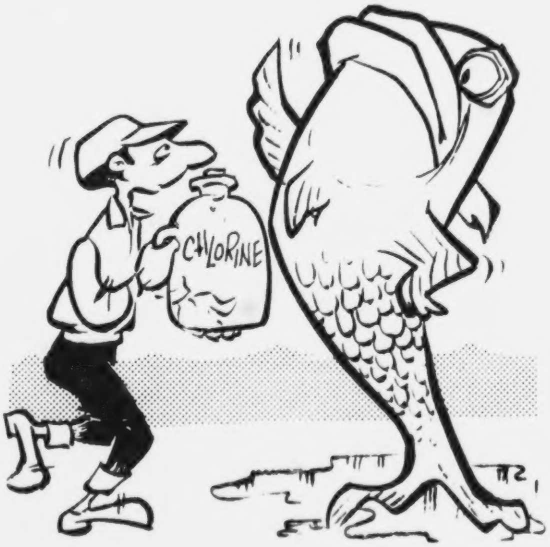
Try to schedule the starting of trickling filters during late April through early June (depends on local conditions). This procedure will produce the most growth during the shortest period of time. Problems avoided will include wet weather flows in the spring, odors in the summer, the dormant bacteria in the winter.

When you have checked out all equipment mechanically, starting up the trickling-filter portion of the plant is very simple. Start the wastewater flow to the filters, observing the rotating arms carefully for smooth operation, speed of rotation, and even distribution of the waste over the media. Time the speed of rotation, record the flow rate, and log them for future reference.

NOTE: Starting up recirculation may be tricky in some plants. The pump may run out of water before the return from the filter has begun. You may have to block the channels (launders) in the clarifier and build up extra water before starting the pump. Conversely, shutting off recirculation will result in a surge of water because the pump is no longer removing water, but water is still returning from the filter.

For fixed nozzles, observe the spray pattern. Usually some debris will show up to plug some of the nozzles, the amount depending on how thoroughly the plant was checked out prior to start-up. Be sure to keep the nozzles clear so that the wastewater is distributed over all of the filter media. Regular care is required to keep fixed nozzles working properly.

Several days will pass before any growth starts to develop on the filter media, and up to several weeks will pass before full development occurs. Time of year, weather conditions, and strength of the waste are all factors which will affect the time needed for growth development.



During this period of growth development, an unstable effluent will be produced. This effluent will exert a pollutional load on the receiving waters. Heavy chlorination is usually used during this time to reduce the pollutional load and the health hazard to some extent.

In some locations, such as where fish are threatened, the use of chlorine in this manner may be restricted. If an older plant is being phased out, it may be possible to load the new facilities lightly or intermittently until a full growth is established.

Starting-up of pumps, clarifiers, and other equipment is discussed in other chapters.

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[5] *Contracts for treatment plant construction usually include services of the consultant and contractor to assist in start-up of new facilities. The operator should make full use of these services.*

6.22 Daily Operation

Once growth on the media has been established and the plant is in "normal operation," very little routine operational control is required. Careful daily observation is important. Items to be checked daily are:

1. Any indication of ponding,
2. Filter flies,
3. Odors,
4. Plugged orifices,
5. Roughness or vibration of the distributor arms, and
6. Leakage past the seal.

Refer to the appropriate paragraphs in the following section on operational problems for procedures to correct these conditions.

Operation of clarifiers is interconnected with trickling-filter operation. If the recirculation pattern permits, it is a good idea to return filter effluent to the primary clarifier. This is a very effective odor-control measure. In some plants, increasing the recirculation rate will increase the hydraulic loading on the clarifier. *BE SURE THE HYDRAULIC LOADING REMAINS WITHIN THE ENGINEERING DESIGN LIMITS.* If the hydraulic loading is too low, septic conditions may develop in the clarifier. Excessively high loadings may wash solids out of the clarifier.

Recirculation during low inflow periods of the day and night may help to keep the slime growths wet, minimize fly development and wash off excessive slime growths. Reduce or stop recirculation during high flow periods, if necessary, to avoid clarifier problems from hydraulic overloading. Recirculation of final clarifier effluent dilutes influent wastewater and recirculated sludge improves slime development on the media. Proper recirculation rates help to control snail populations on the media.

You should, by evaluating your own operating records, adjust the process to obtain the best possible results for the least cost. Power costs are a large item in a plant budget. In order to conserve energy, use the lowest recirculation rates that will yield good results. Be careful not to cause ponding or other problems that result from recirculation rates that are too low. Also, reduced hydraulic loadings mean better settling in the clarifiers. This results in less chlorine usage in plants which disinfect the final effluent, since organic matter exerts a high chlorine demand. If filter effluent, rather than secondary clarifier effluent, is recirculated, the hydraulic loading on the secondary clarifier is not affected.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 188 and 189.

6.2A Prepare a check list of items that should be inspected before a trickling filter is placed in service.

6.2B During start-up of a trickling filter, why should the plant effluent be heavily chlorinated?

6.2C Prepare a check list of items needing daily inspection during "normal operation."

6.2D What may happen to a clarifier effluent if the clarifier is not operated within design hydraulic loadings?

6.23 Shutdown of a Filter

Always take a few minutes to plan what you are going to do before shutting down a major plant process or piece of equipment, such as a trickling filter, regardless of the seriousness of the problem or the need for immediate action. Items that must be considered are listed below.

1. What is the incoming flow? Could a shutdown be scheduled at a better time such as during lower flows or when more operators are available to perform the work?
2. How will a shutdown affect the rest of the plant? When the process or equipment is placed back on line, will it cause development of a hydraulic surge which will overload other processes (clarifiers) or equipment (such as chlorinators)?
3. If the filter is to be shut down for maintenance, are the necessary tools and other items (such as funnels, buckets, and lubricants) available?
4. Is there any other task that should be performed while the unit is off the line? For example, does one of the recirculation pumps need repacking?

To shut down a trickling filter, consider the following step-by-step procedures if they apply to your treatment plant:

1. Inspect your plant to be sure there are no abnormal conditions hindering the effectiveness of other operating areas and process units.
2. If the filter to be taken out of service has filter influent and recirculation pumps that supply *ONLY* the filter being shut down, reduce the pump speed to the minimum range. Reducing the speed of a pump will tend to relieve a part of the surge created to the remaining process units when the filter is shut down. Also, due to the reduced load when the pump is started again, the life of variable speed pumps using belt drives will be extended.
3. Stop the influent flow (feed) and recirculation pumps for the filter. Allow the distributor arms to stop moving. Secure the distributor arms. Open the end gates. Restart the pump in order to flush the arms for a few minutes. Do not try to open the gates when the arms are moving.
4. Stop the influent flow (feed) and recirculation pumps for the filter and close the pump discharge valves. Tag and lock out the pump motor starters. The filter distributor will stop rotating soon because no water is flowing out the outlet orifices.

   WARNING. NEVER ATTEMPT TO STOP A ROTATING DISTRIBUTOR BY STANDING IN FRONT OF IT OR GRABBING IT WITH YOUR HANDS.

5. Check the remaining plant parts for proper operation, particularly wet wells and distrubution or diversion structures between the other filters and clarifiers for normal water levels and position of flow control valves.
6. Once the distributor arm has stopped rotating, remove debris and rags from the distributor-arm orifice plates. Also remove from the top of the media any debris and rags which could have been dumped during flushing of the distributor arms.

If the filter is to be left out-of-service for several days or longer, the following steps should be taken.

1. Close the filter underdrain outlet gates to prevent flow from other units entering the underdrain channel.
2. Drain or pump down the underdrain channel to prevent odors and insects from developing in the captured (stagnant) wastewater.
3. Hose down the distributor arms, side walls, vent ducts, and underdrain channels.
4. Remove any grit or debris from the main underdrain collec-

tion channel. Inspect the underdrains and remove any debris in order to prevent stoppages.

5. Check the oil level in the distributor turntable for proper level and the possible presence of water.
6. Inspect the turntable seal.
7. Consider removal of material (biomass) from media if growths are very heavy. If not removed, excessive growths may cause ponding when the filters are restarted. After drying, the material can be removed by the use of a leaf rake. Most of the remaining material will be flushed out when the unit is put back in service.

These steps take a small amount of extra time, but they can prevent unnecessary mistakes or your plant effluent from violating discharge requirements.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 189.

6.2E What is the first thing an operator should do before shutting down a trickling filter?

6.2F What items should be considered when planning to shut down a trickling filter?

6.3 SAMPLING AND ANALYSIS

6.30 Important Considerations

The trickling filter is a biological treatment unit and therefore loadings and efficiencies of the unit are normally determined on the basis of influent characteristics (inflow and biochemical oxygen demand) and required quality of effluent or receiving waters (dissolved oxygen and solids). Detailed procedures for performing the trickling filter control tests are given in Chapter 16, "Laboratory Procedures and Chemistry." The frequency of each test and expected ranges will vary from plant to plant. Strength of the wastewater (BOD), freshness, characteristics of the water supply, weather, and industrial wastes will all serve to affect the "common" range of the various test results.

6.31 Typical Trickling Filter Plant Lab Results

Test	Frequency	Location	Common Range
1. Dissolved Oxygen	Daily	Prim. Effl.	1.0 - 2.0 mg/*L*
2. Settleable Solids	Daily	Influent Final Effl.	5 - 15 ml/*L* 0 - 3 ml/*L*
3. pH	Daily	Influent Final Effl.	6.8 - 8.0 7.0 - 8.5
4. Temperature	Daily	Influent	—
5. BOD	Weekly (Minimum)	Influent Prim. Effl. Final Effl.	150 - 400 mg/*L* 100 - 260 mg/*L* 15 - 40 mg/*L*
6. Suspended Solids	Weekly (Minimum)	Influent Prim. Effl. Final Effl.	150 - 400 mg/*L* 60 - 150 mg/*L* 15 - 40 mg/*L*
7. Chlorine Residual	Daily	Final Effl.	0.5 - 2.0 mg/*L*
8. Coliform Bacteria	Weekly (Minimum)	Final Effl., Chlorinated	50 - 700/100 ml —
9. Clarity	Daily	Final Effl.	1 - 3 ft (0.3 -1 m)

NOTES: Results of tests listed above as "Primary Effluent" may vary at different plants due to the many variations in recirculation patterns and activities of those discharging wastes into the collection system.

Settleable solids tests of the effluent are usually required by regulatory agencies. If your plant is operating efficiently, the settleable solids will be so low as to be unreadable. In this case, record as "Trace" or less than 0.1 ml/*L*.

Tests of trickling-filter effluent for dissolved oxygen, settleable solids, and clarity are sometimes useful in evaluating problems when they occur. Operators should know what range is "common" for their plants.

Frequency of testing may vary widely from that shown in the table. In some locations (near water supply intakes or recreational areas), a much higher frequency may be required by regulatory agencies. For example, a chlorine-residual analyzer with recording chart may be required for continuous monitoring.

An easy test that should be made periodically by the operator is to check the distribution of wastewater over the filter. Pans of the same size are placed level with the rock surface at several points along the radius of a circular filter. The distributor arm should then be run long enough to almost fill the pans. The arm is then stopped and the amount in each pan should not differ from the average by more than 5 percent. If the distribution is not uniform, the orifices and/or the stay rod turnbuckles must be adjusted.

6.32 Response to Poor Trickling-Filter Performance

There are several operational procedures an operator can follow to correct deficiencies in plant performance. The ability to make corrections will depend on your alertness and ingenuity, as well as the design of the collection system and treatment plant. In Section 6.31, the common ranges are listed for a number of lab test results. If your plant is not operating within or near the common ranges for your plant, then you may have problems.

SUSPENDED SOLIDS. An effluent that is high in suspended solids may be expected to affect all the other test results listed. Ordinarily this will be due to three principal factors:

1. Heavy sloughing from the filters,
2. High hydraulic loading or short-circuiting through the secondary or final clarifier, and
3. Shock loading caused by toxic wastes or hydraulic or organic overloads.

Heavy sloughing may be due to seasonal weather changes, a period of heavy organic loading on the filters, or corrective action taken to overcome ponding, filter flies, or other problems (see Section 6.4). High hydraulic loading or short-circuiting in the secondary clarifier will carry the light solids from the filters over the weirs. If a plant is not receiving more flow than it was designed to handle, you may be able to adjust recirculation rates or the flow pattern (see Fig. 6.6, page 170) to reduce the clarifier loading. Refer to Chapter 5, "Sedimentation and Flotation," for solutions to problems created in clarifiers by short-circuiting and sludge withdrawal.

BOD. The effluent BOD will generally go up or down along with the suspended solids. This is not always the case, however. Anything you can do to assure that the wastewater arrives at the plant in an aerobic condition will reduce the organic load (and odors); consequently, the effluent BOD will be lower. Aeration has been used in *FORCE MAINS*[6] with some degree of success when applied properly.

The recirculation rate and flow pattern will affect effluent quality. These can be varied experimentally, keeping in mind that too low a recirculation rate leads to filter flies and ponding, while too high a rate may cause excessive sloughing or hydraulically overload the clarifiers. Biological systems respond to a change in their environment and establish a balance with the existing conditions, but it takes time. If you change your operation, give your plant a couple of weeks to reach an equilibrium state (level out) before you decide whether or not you have helped the situation.

The shortcomings of the BOD test must be recognized. This test is difficult to use as a daily operational tool unless the influent BOD remains fairly constant. If an industry dumped some wastewater with a high BOD, you could not measure the BOD and base your operational adjustments on the test results because they will not be available for five days. You will have to adjust your operation on the basis of your experience and the probable BOD. Use the chemical oxygen demand (COD) test to estimate rapid changes in the influent load. For control purposes, the COD test procedure may be altered and a very short waiting time may be acceptable.

SETTLEABLE SOLIDS. High settleable solids in the effluent mean that solids are being carried over the clarifier weir. This also means that the suspended solids will be high. Refer to the paragraph in this section on suspended solids for corrective action.

DISSOLVED OXYGEN (DO). One of the principal functions of a trickling filter plant is to stabilize the oxygen-demanding substances in the wastewater being treated. This is achieved by the addition of dissolved oxygen to the water. If the suspended solids and BOD are within range, the DO is almost certain to be in range also. Increased recirculation will increase the DO. In plants with very low inflows, excessive detention time in the clarifiers may cause the problem. If this is the case, remember that any agitation of the effluent will cause it to pick up dissolved oxygen. If the elevation is available, a staircase type of effluent discharge will help; otherwise, it may be necessary to aerate the effluent using compressed air or paddle-type aerators (see Chapter 8, "Activated Sludge").

CHLORINE DEMAND. Difficulty in maintaining a chlorine residual in the effluent (assuming normal detention period) will be due primarily to excessive solids in the effluent. Refer to the paragraph on Suspended Solids.

CLARITY. Clarity of the effluent also is related primarily to the amount, size, shape, and characteristics of the suspended solids in the effluent. In some cases, industrial or food-processing wastes may cause discoloration. Trickling-filter effluents tend to be slightly turbid.

pH. The pH of the effluent should move from whatever value is found in the influent toward neutral (a pH of 7.0). Normally the influent pH will be somewhat acidic (a pH of less than 7.0) and will move up to 7.0 or slightly higher. Other than pH changes caused by industrial waste dumps or other unusual wastes entering the plant, the pH will remain "normal" as long as the suspended solids and BOD are within reasonable limits. Corrective action requires chemical neutralization.

COLIFORM COUNT. Where the bacterial count requirement must be met, excessive solids in the effluent are a serious problem. Even with high chlorine residuals, sporadic results occur because some particles are not penetrated completely by the chlorine. If in-plant corrections do not solve the solids carry-over problem, some type of water treatment plant technique, such as coagulation and settling, or sand or diatomaceous earth filters, may have to be used. Good disinfection is achieved if the previous treatment processes do their job.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 189.

6.3A How would you determine if the distribution of wastewater over a trickling filter is even?

6.3B List the laboratory tests used to measure the efficiency of a trickling filter.

6.3C (1) Calculate the efficiency of a trickling filter plant if the suspended solids of the plant influent is 200 mg/*L* and the plant effluent suspended solids is 20 mg/*L*.

(2) What is the efficiency of the trickling filter only if the effluent suspended solids from the primary clarifier (wastewater applied to filter) is 140 mg/*L* and the effluent suspended solids remains at 20 mg/*L*.

END OF LESSON 1
OF 3 LESSONS
ON
TRICKLING FILTERS

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[6] *Force Main. A pipe that conveys wastewater under pressure from the discharge side of a pump to a point of gravity flow.*

DISCUSSION AND REVIEW QUESTIONS

(Lesson 1 of 3 Lessons)

Chapter 6. TRICKLING FILTERS

Write the answers to these questions in your notebook before continuing.

1. Draw a sketch of a trickling filter and label the essential parts.
2. Why is recirculation important in the operation of a trickling filter?
3. Why should a trickling filter be checked carefully before a new one is started or an existing one is placed in service again?
4. Why would the efficiency of waste removal by a new trickling filter be low during the first few days?
5. What would you do if laboratory results or visual inspection indicated a sudden drop in efficiency of a trickling filter?
6. Calculate the suspended-solids removal efficiency of a trickling filter plant if the influent suspended solids were 360 mg/*L* and the effluent suspended solids were 40 mg/*L*.
7. Why do laboratory test results for trickling filter plants vary from
   a. plant to plant?
   b. month to month within a plant?
8. What steps would you follow when shutting down a trickling filter?

CHAPTER 6. TRICKLING FILTERS

(Lesson 2 of 3 Lessons)

6.4 OPERATIONAL STRATEGY

In actual operation, the trickling filter is one of the most trouble-free types of secondary treatment. This process requires less operating attention and control than other types. Where recirculation is used, difficulties due to *SHOCK LOADS*[7] are less frequent and recovery is faster. Suspended solids in the trickling-filter effluent tend to make the effluent somewhat turbid; thus a poorer quality effluent due to shock loads may not be visibly evident. Recirculation is used to maintain a constant load on the filter and thus produce a better quality of effluent. However, there are some problems which include ponding; odors; insects; and, in colder climates, freezing. These problems are all controllable, and in most cases, preventable.

6.40 Daily Operating Procedures

Daily operation of a trickling-filter plant is in accordance with Section 6.22, "Daily Operation." *USE THE LOWEST RECIRCULATION RATES THAT WILL PRODUCE GOOD RESULTS* (meet NPDES permit requirements), but not cause ponding or other problems. Low recirculation rates conserve energy and minimize plant operating costs. In order to produce good results on a continuous basis, the operator must observe and record those items which are critical to the wastewater treatment process.

Successful operation of a trickling-filter plant requires routine observation of the process units, analysis of plant inflows to obtain wastewater characteristics and determination of the water quality of the plant effluent. An alert operator will note changes in process units by observing various physical factors such as the flow rate or height over weirs, launder levels, amount of scum on a clarifier, the appearance of the effluent, the rotation of filter distributor arms, the spray pattern, the color of the media, and odors which indicate a change in the biological treatment system. Changes in any of these factors require investigation to identify the cause and to determine necessary corrective action.

Measure and record all important process factors. Plant inflows are measured by the plant influent flow meter. Usually these flows produce similar daily patterns on the recording chart during dry weather. At some plants, similar patterns will be produced during certain storm conditions. Laboratory analyses of samples from various process stages, including plant influent, primary effluent, and secondary clarifier effluent, will indicate the water quality changes taking place in the plant. Most samples should be analyzed to determine the temperature, pH, dissolved oxygen, BOD, COD, and settleable solids. Effluent samples should be analyzed for chlorine residual and the most probable number of coliform group organisms in addition to the usual water quality indicators. All of this information is used by the operator to adjust and control the treatment processes.

Trickling-filter plants can be operated on the basis of two loading criteria:

1. Hydraulic loading, gallons per day per square foot; and
2. Organic loading, pounds of BOD per day per 1000 cubic feet of media.

Section 6.7, "Loading Criteria," shows how to calculate these loadings. Operators should attempt to maintain a fairly constant hydraulic loading on each trickling filter by adjusting the recirculation rate. Adjust the recirculation rate to maintain a DO from 1.5 to 2.0 mg/*L* in the filter effluent. The recirculation rate should not be so low as to allow ponding to develop. Organic loadings should be calculated on a weekly basis and compared with plant effluent suspended solids and BOD. If the plant effluent BOD or suspended solids are changing, look for changes in the hydraulic and organic loadings.

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[7] *Shock Loads. The arrival at a plant of waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and sloughing off of the growth or slime on the trickling-filter media. Organic or hydraulic overloads also can cause a shock load.*

The plant effluent is the main indicator of how effective a trickling filter plant is working. If the quality of the plant effluent starts to drop as shown by increases in the effluent BOD or suspended solids, then changes must be made in the operation of the plant. Operational changes available to the operator include changes in the recirculation rates and change in the operation of the trickling filters from parallel to series operation or vice versa.

One way to detect changes in plant effluent and select corrective action is by the use of a trend chart such as the one shown in Figure 6.7. To use a trend chart, record the day of the month and day of the week along the bottom. Determine what you consider are the most important operational factors for your plant (such as plant influent flow and effluent suspended solids) and draw a scale for each factor along the side. Plot the results on a daily basis and look for any trends. If the effluent suspended solids start to increase, look for the cause (increased inflow or possibly too low a hydraulic loading) and select corrective action.

Seasonal changes will have an impact on biological treatment processes and the quality of your plant effluent. Change will occur when the weather changes from cold to warm and again when it changes from warm to cold. Changes in plant influent characteristics caused by discharges from canneries, meat packing houses, or metal plating processes may require the operator to change recirculation rates or mode (sequence) of filter operations. Operators have several methods of adjusting treatment processes, but you must be able to recognize what you can adjust and how you can control the treatment processes in your plant. The next section, "Response to Abnormal Conditions," provides details on how to correct problems.

Figure 6.7 shows the results from the operation of an actual trickling filter. The influent and effluent data plotted are seven-day moving averages in order to smooth out daily fluctuations and to reveal trends. Procedures for calculating moving averages are explained in Chapter 18, "Analysis and Presentation of Data."

Examination of Figure 6.7 reveals the value of using trend charts and plotting the moving averages. During the week starting on Monday, January 24, the effluent BOD increased considerably. On the first of February the effluent BOD was still high. What happened? How could the effluent BOD be reduced to previous levels?

Influent BOD and suspended solids values were fairly high during January and fluctuated considerably from day-to-day (the actual variation was smoothed out by plotting the moving average). Some of this variation was due to a storm on January 11 (high influent suspended solids) and another storm on January 20 (flows slightly above design capacity). These fluctuations probably caused an excessive loss of the biomass (high effluent suspended solids from January 10 to 26). Also a period of cold weather during the latter half of January reduced the organism activity and thus the ability of the organisms in the biomass to remove the BOD from the effluent.

What should the operator do during these conditions? Recirculation should be increased to reduce the effluent BOD. Influent conditions should be watched more closely in order to maintain more constant hydraulic and organic loadings on the trickling filters. These actions were instituted on Monday, February 7, after reviewing data and plotting the moving averages. By Tuesday, February 16, the plot of the effluent BOD moving average was back down to typical values. Perhaps if effluent COD values were used for operational control, the trend of increasing effluent BOD values could have been identified and corrected sooner.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 189.

6.4A What is the major consideration for daily operation of a trickling filter?

6.4B Recirculation rates should be adjusted to maintain a DO of from ______ to ______ mg/*L* in the filter effluent.

6.41 Response to Abnormal Conditions

Every wastewater treatment plant will face unusual or abnormal conditions. How successfully these unusual situations are handled depends on the advance planning and preparations taken by the plant operator. In many cases, what is an abnormal operation condition in one plant may be handled as a routine operating procedure in another plant. This is because the operator took the time to review the potential situation and developed a plan to cope with the unusual event.

6.410 Ponding

Ponding usually is the result of excessive organic loading without a corresponding high recirculation rate. Another cause of ponding can be the use of media which are too small or not sufficiently uniform in size. In non-uniform media, the smaller pieces fit between the larger ones and thus make it easier for the slimes to plug the filter. If this condition exists, replacement of the media is the most satisfactory solution. Other causes of ponding include a poor or improper media permitting cementing or breakup, accumulation of fibers or trash in the filter voids (spaces between media), a high organic growth rate followed by a shock load and rapid uncontrolled sloughing, or an excessive growth of insect larvae or snails which may accumulate in the voids. Ponding results from a loss of open area in the filter. If the voids are filled, flow tends to collect on the surface in ponds.

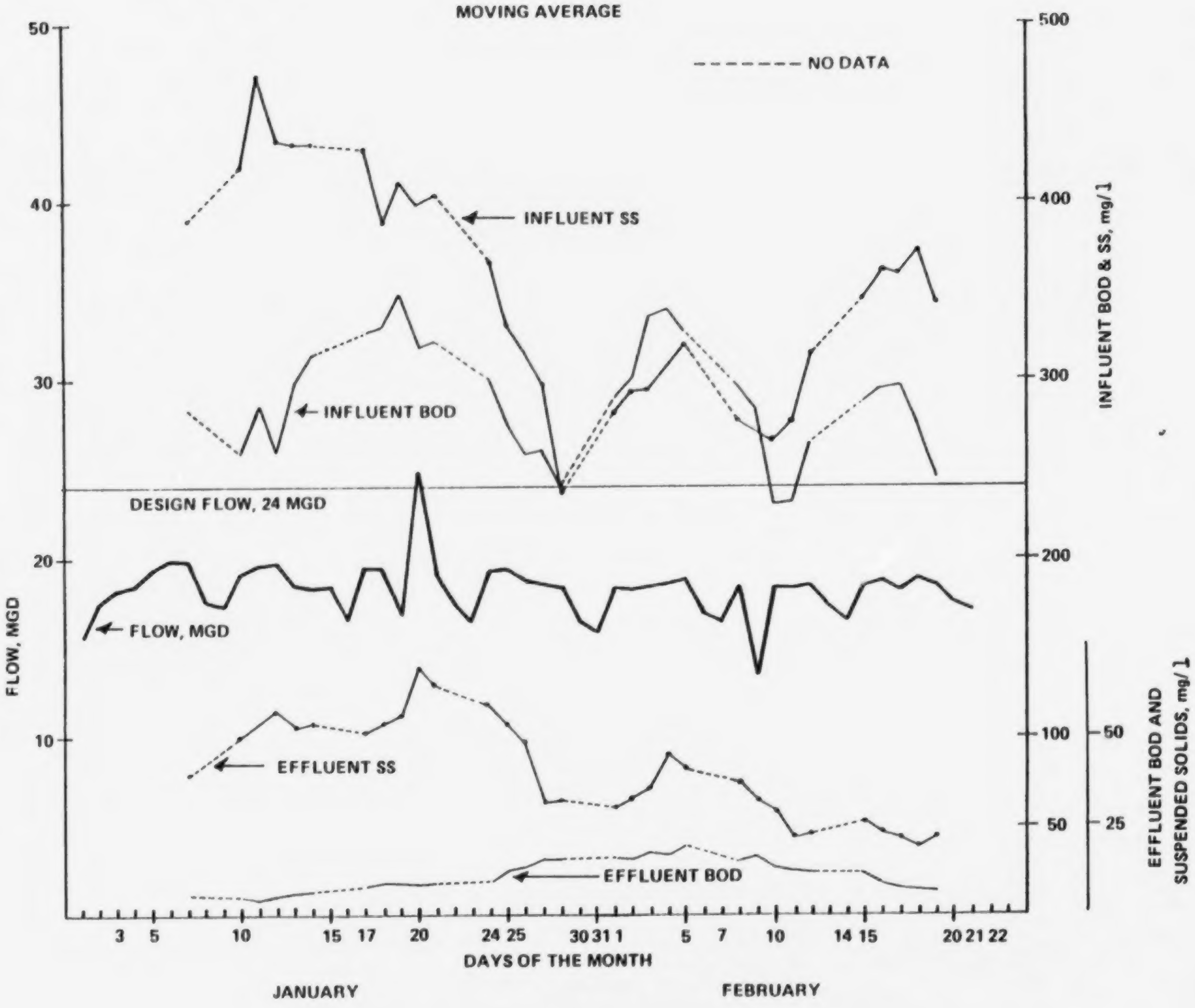


Fig. 6.7 Typical trend chart for a trickling filter plant

The cause of ponding must be located since it may increase rapidly and take over large areas of the filter. Increasing the hydraulic loading by increasing the recirculation ratio or adjusting the orifices on the distributor assembly so that it distributes flow more evenly is likely to flush off some of the heavier portions of the biological film and may slowly cure this condition.

Minor ponding, which may occur from time to time, can be eliminated by any of several methods, including the following:

1. Spray filter surface with a high pressure water stream. Sometimes stopping a rotary distributor over the ponded area will flush the growth from the voids. One way to do this is to shut off the flow momentarily, wait for the distributor to stop, move the distributor to the problem area, and then restart the flow while keeping the distributor over the ponded area.
2. Hand turn or stir the filter surface with a rake, fork, or bar. Remove any accumulation of leaves or other debris.
3. Dose the filter with chlorine at about 5 mg/*L* for several hours. If done during a period of low flow, the amount of chlorine used is held to a minimum.
4. If it is possible to flood the filter, keeping the media submerged for 24 hours will cause the growth to slough somewhat. Keep the surface of the media covered, but don't let the water rise high enough to get in the distributor bearings. Under these conditions, the growths tend to become anaerobic and loosen or liquefy. The resulting liquid is a mess to dump and must be carefully released to avoid violating NPDES discharge requirements.
5. Shut off flow to the filter for several hours. The growth will dry and can be removed by the use of a leaf rake. Most of the remaining material will be flushed out when the unit is put back in service.

Be sure to keep in mind that your primary purpose is to turn out an effluent of consistently good quality. With this in mind, the above corrective actions are listed in order, starting with procedures that will least affect the effluent. If at all possible, ponding should be corrected *BEFORE* it becomes serious. Items 4 and 5 are drastic measures. However, the job must be done so that full efficiency of the filter is restored. In cases 4 and 5, more chlorine will be needed for effluent disinfection. Where dechlorination is required to protect fish in the receiving stream, more chemicals also will be needed for this purpose until the filters are again operating normally.

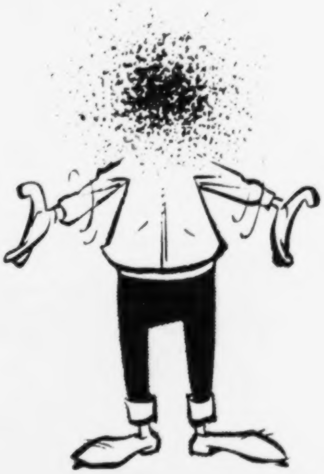
6.411 Odors

Since operation of trickling filters is an *AEROBIC*[8] process, no serious odors should exist. The presence of foul odors indicates that *ANAEROBIC*[9] conditions are predominant. Anaerobic conditions are usually present under that portion of slime growth which is next to the media surface. As long as the surface of the slime growth (zoogleal film) is aerobic, odors should be minor. Corrective measures should be taken immediately if foul odors develop. The following are guidelines for maintaining trickling filters to prevent odor problems.

1. Do everything possible (such as prechlorination or preaeration) to maintain aerobic conditions in the sewer collection system and in the primary treatment units.
2. Check ventilation in the filter. Heavy biological growths or obstructions in the underdrain system will cut down ventilation. Examine ventilation facilities such as the draft tube or other inlets for stoppages. If necessary, force air into underdrains using mechanical equipment such as fans or compressors. Natural ventilation through a filter will occur if the vents are open and the *DIFFERENCE* between air temperature and filter temperature is greater than 3°F (2°C).
3. Increase the recirculation rate to provide more oxygen to the filter bed and increase sloughing.
4. Keep the wastewater splash from the distributor away from exposed structures, grass, and other surfaces. If slime growths appear on sidewalks, inside walls of the filter or distributor splash plates, remove them immediately.
5. In some cases during hot weather, odors will be noticeable from filters in good condition. If these odors are a serious problem (close neighbors), the situation can sometimes be resolved with one of the commercially available *MASKING AGENTS.*[10]
6. For covered filters, a forced-air ventilation system and odor control of the exhaust air stream is usually provided. Refer to the plant O & M manual and/or the manufacturer's literature for proper operation of this equipment. A covered filter and odor control system do not substitute for good operation and housekeeping procedures. The other points covered in this section will still apply. However, where uncovered filters have become a problem (such as in a nearby housing development), the addition of a cover and an odor control system could solve the problem.

6.412 Filter Flies

The tiny, gnat-size filter fly (psychoda) is the primary nuisance insect connected with trickling-filter operations. They are occasionally found in great numbers and can be an extremely difficult problem to plant operating personnel as well as nearby neighbors. Preferring an alternate wet and dry environment for development, the flies are found most frequently in low-rate filters and are usually not much of a problem in high-rate filters. Control usually can be accomplished by the use of one or more of the following methods.



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[8] *Aerobic (AIR-O-bick). A condition in which "free" or dissolved oxygen is present in the aquatic environment.*

[9] *Anaerobic (AN-air-O-bick). A condition in which "free" or dissolved oxygen is* NOT *present in the aquatic environment.*

[10] *Masking Agents. Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable. "Neutral" odors may be the most desirable.*

1. Increase recirculation rate. A continuous hydraulic loading of 200 gpd/sq ft (8 cu m/day/sq m) or more will keep filter fly larvae washed out of the filter.
2. Keep orifice openings clear, including end gates of distributor arms. The gates can be opened slightly to obtain a flushing action on the walls.
3. Apply approved insecticides with caution to filter walls and to other plant structures.
4. Flood filter for 24 hours at intervals frequent enough to prevent completion of the life cycle. This cycle is as short as seven days in hot weather. A poor effluent will result from this practice and should be carefully monitored.
5. Dose with about 1 mg/*L* chlorine for a few hours each week. The chlorine will cause some of the slime layer to slough off. Too much chlorine will remove too much of the slime layer, reducing BOD removal and lowering the effluent quality of the plant.
6. Shrubbery, weeds, and tall grass provide a natural sanctuary for filter flies. *GOOD GROUNDS MAINTENANCE AND CLEANUP PRACTICES WILL HELP TO MINIMIZE FLY PROBLEMS.*

6.413 Cold Weather Problems

Cold weather usually does not offer much of a problem to wastewater flowing in a pipe or through a clarifier. Occasionally, however, wastewater sprayed from distributor nozzles or exposed in thin layers on the media may reach the freezing point and cause a build up of ice on the filter. Several measures can be taken to reduce ice problems on the filter.

1. Decrease the amount of recirculation, provided sufficient flow will remain to keep the filter working properly.
2. Operate *TWO-STAGE FILTERS*[11] in parallel rather than in series.
3. Adjust orifices and splash plates to reduce the spray effect.
4. Construct wind screens, covers, or canopies to reduce heat losses.
5. Break up and remove the larger areas of buildup.
6. Partially open end gates to provide a stream rather than a spray along the retaining wall.
7. Add hot water or steam to the influent if necessary.

Although the efficiency of the filter unit is reduced during periods of icing, it is important to keep this unit running. Taking the unit out of service will not only reduce the quality of the effluent but may lead to additional maintenance problems, such as ice forming, with the possibility of structural damage. Also, moisture may condense in the oil and damage the bearings.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 189.

6.4C What are some of the causes of ponding?

6.4D How would you correct a ponding problem?

6.4E How would you control odor problems in a trickling filter?

6.4F Trickling filter flies can be controlled by what methods?

6.4G Why should a trickling filter not be taken out of service during icing conditions?

6.414 Plant Inflow

Plant inflows may be considered abnormal when there are high flow rates, extreme levels of suspended solids or biochemical oxygen demand (BOD), or inflow of a septic influent. High flow rates (greater than 2.5 times the **A**verage **D**ry **W**eather **F**low (ADWF) usually result from one of four sources:

1. Storm water infiltration,
2. Broken collection system pipe that permits excess inflow from groundwater or a creek or stream,
3. Clearance of a main line sewer stoppage and the release of the backed-up wastewater, or
4. Industrial discharges.

The plant operator will always be aware when condition one will occur; however, conditions two, three, and four may occur without warning, yet the plant operator is often the first to know. Each of the four conditions has a common characteristic, *EXCESS FLOW*. This excess flow may load the plant to its hydraulic capacity or exceed it. Conditions three and four can impose other loads which the operator must also consider. These loads include heavy solids and BOD; septicity; and in the case of the industrial discharge, a toxic material or load harmful to the biological treatment processes.

In a trickling-filter plant, the operator usually is provided with three methods of controlling abnormal flows:

1. Number of filters in service (adjusts loading rates),
2. Recirculation capacity (adjusts DO and dilution), and
3. Series or parallel filter operation (adjusts loading rates).

What can a trickling-filter plant operator do to control plant effluent during abnormal flows? The following paragraphs suggest methods for you to consider when operating your plant. If you understand how your plant operates and how to adjust for abnormal conditions, you can select the best procedures.

CONDITION ONE. HIGH FLOW DUE TO STORM-WATER INFILTRATION

A. If collection system is clean from good maintenance or from recent storms, the high flows usually will dilute the solids and BOD and possibly reduce influent and solids loadings to below the ADWF loading.

B. If A above is true, then the influent could have a higher than normal DO.

PLANT OPERATION PLAN

1. Reduce or stop filter recycle or recirculation flows.
    a. Recycling flows to a filter are for dilution, DO increase, and to maintain the hydraulic load on the filter media.
    b. Reduction in recycle flows in some plant designs also will reduce the hydraulic loading on the secondary clarifiers, thus providing for a better removal of solids sloughed from the filter resulting from high flows.

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[11] *Two-Stage Filters. Two filters are used. Effluent from the first filter goes to the second filter, either directly or after passing through a clarifier. (See Fig. 6.6, page 168.)*

2. Place filters in *PARALLEL OPERATION*.[12] Since the storm water has diluted the inflow, the DO will be higher in the inflow. Loading each filter equally (half of total flow to each filter) instead of forcing the total flow across each filter will reduce sloughing and keep each filter functioning.
3. Keep influent screening equipment operating and check often, especially if collection system is a combined sanitary- and storm-water system which may have leaves and other debris in the flow.
4. Increase post chlorination rates to match flows in order to insure proper disinfection.

Other adjustments that may be considered when high flows occur include:

5. Use the collection system as a storage reservoir by throttling the plant influent gate or by changing pumping elevations of the pumping start and stop cycles.

   NOTE: a. This should be done only when the lowest manhole elevation in the system is known and the maximum water level can be held at least 2 feet (0.6 m) below the manhole rim elevation to prevent system overflow.

   b. Beware of pump problems developing when the wet well water level is higher than normal. High water levels reduce the head a pump must work against, which results in a higher pumped flow, which calls for an oversized pump motor.
6. Use chemicals on the influent to reduce solids and BOD load by causing chemical precipitation in the primary clarifiers.
7. Inspect the collection system for major defects and develop programs to reduce inflow and infiltration.
8. Reduce pumping of digester supernatant back to headworks in order to keep the hydraulic loading as low as possible.
9. Reduce the pumping of sludge to anaerobic digesters because sludge temperature will be lower than usual due to the lower temperatures of the storm waters.

CONDITION TWO. HIGH FLOWS DUE TO A BROKEN COLLECTION SYSTEM PIPE

High flows consist of relatively clear water from a creek or stream above broken pipe or from groundwater infiltration.

PLANT OPERATION PLAN

1. Operate plant using same procedures as outlined under CONDITION ONE.
2. Have broken pipe repaired as soon as possible.

CONDITION THREE. HIGH FLOWS DUE TO CLEARANCE OF MAIN LINE SEWER STOPPAGES

A. Surge or slug of high flows results when stoppage is cleared.

B. Influent septic, odorous, and probably has a high solids and BOD load.

PLANT OPERATION PLAN

1. Increase prechlorination rates in order to:
   a. Control odors, and
   b. Reduce influent BOD load.
2. Store released surge in collection system and allow to flow slowly into plant.
3. Place filters in *SERIES OPERATION*.[13] Apply the initial loading to the first filter and have it perform as a roughing filter to reduce the shock load on the next filter. See Section 6.13, "Roughing Filter," for a more complete description.
4. Increase recycle rates to both filters in order to:
   a. Increase dilution of influent to filter, and
   b. Increase DO content of water applied to filter.
5. Increase post-chlorination rates to maintain effective disinfection.
6. Frequently skim surface of primary clarifier to keep grease and other floatables off the filter media and out of the orifices on the distributor arms.
7. Frequently pump sludge from bottom of primary clarifier to reduce solids load to filters.
8. Stop recycle flows of supernatant or other heavy solids back to plant influent or to primary clarifier. These flows would complicate the filter problems.

Other adjustments that may be considered when a septic main line sewer stoppage is cleared include:

9. Feed chemicals into plant influent, and
10. Arrange with collection-system maintenance crews to inform plant when a system stoppage is cleared and expected to hit the plant.

CONDITION FOUR. INDUSTRIAL DISCHARGES

Influent conditions that may be expected following industrial discharges are listed below, followed by recommended plant operating plans for each condition.

A. High flows with normal solids and BOD loadings.

PLANT OPERATION PLAN

Operate plant using same procedures as outlined under CONDITION ONE.

B. High flows with high solids loadings.

PLANT OPERATION PLAN

Operate plant using same procedures as outlined under CONDITION THREE.

C. High flows and toxic material in plant influent. A toxic material often only can be detected if the industry notifies the plant or if the influent sampling equipment monitors for a specific chemical and sends out an alarm. Typical toxic conditions include an excessively high or low pH, or the presence of excess amounts of ammonia, heavy metals, or hydrocarbons. Unfortunately, in most plants the influent is not monitored continuously for high or low pH or the specific toxic material which causes the problem. Usually the operator never realizes that something toxic has hit the plant until a day or two later when the biological process is not functioning and the solids content in the plant effluent is high.

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[12] *Parallel Operation.* *When wastewater being treated is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit. Also see SERIES OPERATION.*

[13] *Series Operation.* *When wastewater being treated flows through one treatment unit and then flows through another similar treatment unit. Also see PARALLEL OPERATION.*

PLANT OPERATION PLAN

1. If a toxic chemical is known (it usually is not), a neutralizing agent may be added to the influent. For example, chlorine is used to counteract cyanide. If a high pH is detected (in excess of 9.0), lower the pH by adding an acid such as acetic or sulfuric. If the pH is below 6.0, increase the pH with caustic soda (sodium hydroxide — Na (OH)). If the pH is not properly adjusted you could produce toxic hydrogen cyanide or cyanogen chloride. Over chlorination may destroy the entire biological process.
2. Operate the plant filters in series with a high recirculation rate in order to dilute the influent and bring the pH towards neutral. The first filter may slough and lose its biological culture from the media, but you may save the biological growths on the second filter. If the filters are operated in parallel, the toxic flow may strip the media in both filters of biological growths.

Other adjustments that may be considered when a toxic waste reaches a trickling filter include:

3. Store toxic waste in collection system until diluted by other wastewater and/or gradually release during high flows.
4. Locate industry responsible for toxic discharge and require industry to start a source control program. Be sure your sewer-use ordinances are enforced.
5. Restrict toxic discharges from industry. Allow releases to occur slowly, rather than in slugs or large batches. Also allow discharges to be released when plant can handle toxic wastes. Another type of restriction on very toxic agents is to allow discharges to the collection system only when tested, neutralized, and plant flows are sufficient to dilute the discharge. Under these conditions the wastewater treatment plant may handle all incoming wastewater without special procedures and also without the possibility of the plant processes becoming upset.

Some treatment plants will have more alternatives than other plants due to design considerations and equipment, but the best option is to have a plan for any abnormal condition that could occur at your plant.

6.415 *Operational Problems with Upstream or Downstream Treatment Processes*

When a treatment process has operational problems, you should be aware of the possible compensating adjustments or actions that may be available to maintain plant effluent quality.

1. Screening

   If a comminutor or other screening equipment has failed, the operator of a trickling-filter plant should frequently clean the bypass-bar rack to remove as much of the debris as possible. Frequent skimming of the primary clarifiers also will help to reduce plugging of the orifices in the distributor arm.

   The frequency of flushing the distributor arms should be increased to daily to keep them clean. Also, the distributor orifices should be cleaned more frequently to insure an even application of wastewater to the media surface. The recirculation and influent feed pumps also should be checked for proper flows and discharge pressures because the pump impellers may become plugged or loaded with debris, thus requiring shutdown of the pumps for cleaning.
2. Grit

   Large volumes of grit will seldom reach the filters unless a primary clarifier is bypassed or excessively overloaded with flow. When the primary clarifier is excessively hydraulically overloaded, the grit will be deposited in the underdrain which will allow septic dams and conditions to develop and produce odors. Grit also can increase ponding on a filter by filling the small voids between the media and reducing the downward flow of water. When this occurs the filter is taken out of service, flooded, drained, the media washed off with water from a hose under high pressure, and the underdrain cleaned.
3. Primary Clarifier

   When a primary clarifier is out of service in a trickling-filter plant, operate the filters in series. Use the first filter as a roughing filter to remove the larger pieces of suspended wastes. The first filter can perform satisfactorily this way for several weeks, but will require a cleanup of the filter afterwards. This procedure should keep the second filter healthy and leave only one filter to clean.
4. Secondary Clarifier

   When a secondary clarifier is out of service, solids in the effluent will increase. Operate the filters in series. Apply normal recirculation flows to the first filter and do not recirculate to the second filter. Apply the normal flow as evenly as possible to the second filter. This procedure should minimize sloughing from the media on the second filter for a while and, hopefully, until the secondary clarifier is back in service.

   A simple device containing a coarse hardware-cloth screen or a similar device could be installed in the underdrain channel or outlet box to catch the sloughings. The screen would have to be removed and cleaned frequently.
5. Chlorinator

   When one chlorinator is not working, hopefully your plant has another chlorinator. If no other chlorinators are available, reduce the hydraulic load on the secondary clarifiers as much as possible to obtain the best solids removal. If you do not have a standby chlorinator, develop emergency procedures now to chlorinate your effluent when the chlorinator is not working. Some smaller plants use sodium hypochlorite as a standby disinfectant.

6.42 Troubleshooting

Table 6.2 summarizes Section 6.41 and is a quick reference to common problems and suggested ways to correct them. This table is primarily useful as an "idea file" which will help you to avoid overlooking a possible solution to an operating problem. A review of sections 6.01 and 6.02 will also help in deciding on a course of action. Be sure to keep in mind that trickling filters respond slowly to changes. For example, if you change the recirculation rate, the biological system could take several days to stabilize to the new conditions. Therefore, change only one thing at a time, and wait until it has leveled out to evaluate the effects of the change. Also, remember that plant units are interrelated. For example, a change in the recirculation rate (where the recirculation pattern includes a clarifier) will change the hydraulic loading on the clarifier. This will change the efficiency of the clarifier, which will then carry a different amount of solids to subsequent units. If the filter recycle flows do not involve the clarifiers, the flows to clarifiers will not change and the solids-removal efficiency of the clarifier should not change either.

TABLE 6.2 SOLUTIONS TO TRICKLING FILTER PROBLEMS

	Solutions																				
Problems	Increase recirculation rate	Spray (jet) filter surface	Stop distributor to flush out	Rake or stir filter surface	Dose filter with chlorine	Flood filter	Let filter dry out	Check plant influent	Check ventilation	Protect outside areas from splash	Use masking agents	Check exhaust odor control system	Apply insecticides	Keep weeds down	Decrease recirculation	Parallel operation	Reduce spray (adjust nozzles)	Partially open end gates	Keep sludge pumped out of the clarifier	Replacement of media	See Section for details
Ponding	x	x	x	x	x	x*	x*													x*	6.410
Filter Flies	x				x	x*							x	x				x			6.412
Odors	x							x	x	x	x	x									6.411
Icing of the Filter															x	x	x	x			6.413
Low Dissolved Oxygen in Secondary Clarifier	x							x	x										x		
Floating Sludge in Secondary Clarifier								x											x		
High Effluent Suspended Solids															x						

* Drastic measure. See page 178.

The important thing in plant operation is to avoid problems, and the key to avoiding problems is *ALERTNESS*. Many of the common problems develop slowly and go undetected in their early stages. For instance, ponding will occur as a result of a buildup of heavy slime growths. The alert operator, who carefully inspects the filters daily, will detect the developing problem and make corrections. To the casual observer, this operator doesn't have any problems!

ALWAYS
REMAIN
ALERT

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 189 and 190.

6.4H What are four possible sources of abnormal conditions?

6.4I How can an operator adjust the trickling-filter process when excess flows occur?

6.4J How do high flows from the clearance of a main line sewer stoppage differ from high flows caused by a broken sewer pipe?

6.4K Why are toxic industrial discharges difficult to detect until it is too late?

6.4L How are toxic industrial discharges often detected or suspected?

6.4M Why should an operator only make one change at a time in trickling filter operation and wait approximately one week before making another change when attempting to correct a trickling-filter problem?

6.5 MAINTENANCE

6.50 Bearings and Seals (Fig. 6.8)

The bearings in distributors may be located in the base of the center column or at the top. Both types will have a water seal at the base to prevent wastewater leakage. This is to avoid uneven distribution of the wastewater over the media, and also to protect the bearings when they are located in the base. Many older distributors utilized a mercury seal. Mercury should not be used because mercury ions are toxic to living organisms, including operators.

Generally, the bearings ride on removable races (tracks) in a bath of oil. The oil usually specified is a turbine oil with oxidation and corrosion inhibitors added. The manufacturer's literature or the plant O & M manual should specify what types of oil to use. If this information is not available, the representative from any major oil company can recommend a suitable oil.

Be sure to monitor the oil very carefully. The level and condition of the oil are crucial to the life of the equipment, and should be checked weekly. To check, drain out about a pint of oil into a clean container and, if the oil is clean and free of water, return it to the unit. If the oil is dirty, drain it and refill with a mixture of approximately 1/4 oil and 3/4 solvent (such as kerosene), and operate the distributor for a few minutes. Drain again, and refill with the correct oil. (Note: Drawing off some of the oil to check it is important. You can see if the oil is contaminated, and verify that the oil level sensing line is not plugged.)

Water in the oil will appear at the bottom of the oil in the container. If water is found in the oil, either the sealing fluid is low or the gasket must be replaced in mechanical seals. Refer to the manufacturer's literature or the plant O & M manual for instructions.

6.51 Distributor Arms

Work on distributor orifices only after the arms have stopped moving, unless you are using a pressure hose for cleaning and stand outside the filter wall. The distributor arms should be flushed weekly by opening the end dump-gates one at a time. Also clean debris out of the filter each day, cleaning the orifices as often as needed. When there is considerable plugging, you should install a coarse hardware-cloth or similar type screen ahead of the filters, if possible. Screens are easier to clean and good distribution is maintained over the filter media. Observe the distributor daily for smooth operation. If it becomes jumpy, seems to vibrate, or slows down with the same amount of wastewater passing through it, the bearings and races are probably damaged and will require replacement. A thorough oil check each week will probably keep this from happening. Adjust the turnbuckles occasionally on the guy rods to keep the rotating distributor arms at the proper level to provide even flow over all of the media.

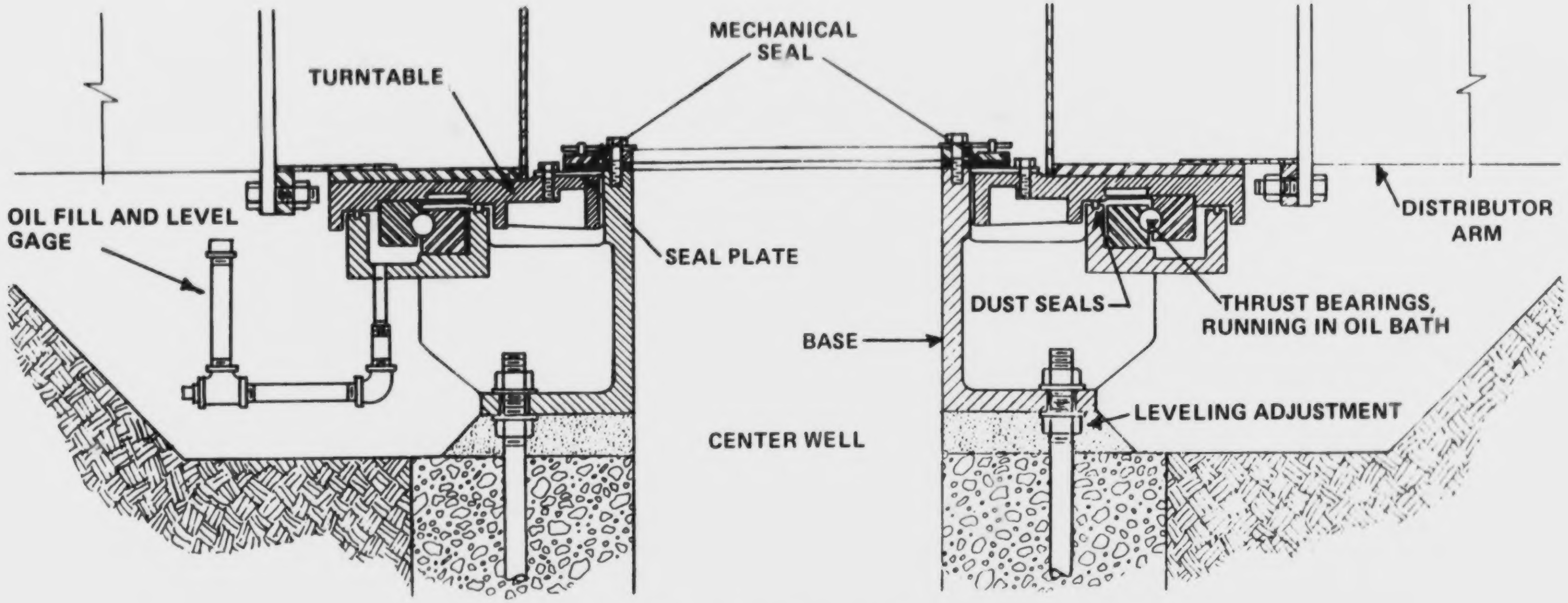
The speed of rotation of the distributor should not be excessive. Rotation of the distributor is due to the reaction of the water flowing through the orifices. This is similar to the backward thrust of a water hose or the spinning of some types of lawn sprinklers. Speed is controlled by regulation of flow through the orifices. (On larger distributors, approximately 1 rpm is normal. The manufacturer's literature or plant O & M manual will state the maximum allowable speed.) If the distributor rotates too fast, it may damage the bearing races on the turntable.

To reduce the speed of rotation, provision usually is made on the front of each arm for orifices which are easily installed (Fig. 6.3, page 164). The reaction of the water flowing through these orifices cancels some of the thrust of the regular orifices. If the speed of rotation is too slow, check for mechanical problems and, if none, increase flow to distributor.

Since most distributors appear rather large and bulky, many operators are surprised to find that they are delicately balanced. As soon as wastewater begins to flow from the orifices, the distributor arm should start to move. The fan-like pattern as the wastewater leaves the deflecting plates should be uniform. If the plates have developed a slime growth that is affecting uniform distribution, the slime should be brushed off.

6.52 Fixed Nozzles

Fixed-nozzle trickling-filter beds are similar to lawn sprinkler systems because the distribution piping system is buried under the media and feeds into riser pipes spaced evenly across the


MECHANICAL SEAL
TURNTABLE
OIL FILL AND LEVEL GAGE
SEAL PLATE
DISTRIBUTOR ARM
DUST SEALS
THRUST BEARINGS, RUNNING IN OIL BATH
BASE
LEVELING ADJUSTMENT
CENTER WELL

CENTER ASSEMBLY BEARING AND SEAL ARRANGEMENT

Fig. 6.8 Trickling filter bearing and mechanical seal

filter bed. Each riser pipe is equipped with a spray head called a "nozzle" at the top of the riser pipe above the filter-bed media (Figure 6.5, page 168). The nozzles are designed to handle high flows at low pressures and to pass some debris that would be in the wastewater in order to prevent plugging of the nozzle. The riser pipes and nozzles are spaced evenly just like a lawn irrigation system in order to provide equal distribution of water on the filter media surface.

Fixed nozzles should be observed frequently to determine that each is putting out a desired spray pattern and evenly covering the media.

These nozzles may become plugged or flow restricted, thus causing poor spray patterns just like a plugged or restricted orifice will on a rotating distributor arm. If a nozzle is not spraying properly, the system should be shut down. In some installations the feed distribution pipe to that row of nozzles may be shut off by closing the valve, thus stopping water flow to those nozzles in that particular row. On the faulty nozzle, the ball is removed and the rags or debris are removed from the cone and deflector. Proper cleaning may require turning the system on, blowing the riser pipe out to remove the stoppage, and then re-assembling the nozzle.

If frequent plugging is a problem, a screen may be installed ahead of the filter pumps or siphon to keep the rags and debris out of the distribution system and nozzles.

6.53 Underdrains

The underdrains are buried under the filter bed. Usually cleanouts or flusher branches are located on the head end of each line or channel for flushing to remove sludge deposits or debris from the underdrain system. If flushing will not clear the line and your agency or city's collection system maintenance section has a high velocity cleaner for cleaning sewer lines, borrow their services for an hour or so and have them clean the underdrains. You may wish to schedule this cleaning procedure every three to six months in order to keep the underdrain system open and clear. A clear underdrain system provides for a fast carry off of filter bed effluent, does not restrict air flow for media ventilation, and reduces problems caused by odors, septic conditions and ponding.

6.54 Recirculation Pumps

Refer to Chapter 15, "Maintenance," for information on how to maintain recirculation pumps.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 190.

6.5A What is the purpose of the seal in a rotary distributor?

6.5B Why should you drain some of the oil from the distributor each time it is checked?

6.5C How would you slow down the rotational speed of a distributor?

6.5D What maintenance should be done on trickling-filter underdrains?

6.6 SAFETY

In order to work around a trickling filter safely, several precautions should be taken. *FIRST, SHUT OFF THE FLOW TO THE FILTER AND ALLOW THE DISTRIBUTOR TO STOP ROTATING BEFORE ATTEMPTING TO WORK ON IT.* On all but the very small units, the force of the rotating distributor arms is about the equivalent of a good-sized truck. *YOU JUST CAN'T REACH OUT AND STOP ONE WITHOUT ENDANGERING YOURSELF.* Serious injuries can result.

The slime growth on a filter is very slippery. *EXTREME CARE SHOULD BE TAKEN WHEN WALKING ON THE FILTER MEDIA.* Rubber boots with deeply ridged soles will help your footing. Do not carry oil in glass containers.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 190.

6.6A Why should the flow to a trickling filter be shut off before attempting to work on the filter?

6.6B Why should an operator walk carefully on the filter media?

END OF LESSON 2
OF 3 LESSONS
ON
TRICKLING FILTERS

DISCUSSION AND REVIEW QUESTIONS

(Lesson 2 of 3 Lessons)

Chapter 6. TRICKLING FILTERS

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 1.

9. Define the term *SHOCK LOAD.*
10. How would you correct a ponding problem?
11. Why should a ponding problem be corrected as soon as possible?
12. What action would you take to prevent odor problems from developing in a trickling filter?
13. Why should wastewater be kept from leaking into the bearings of the distributor base?
14. Why should the flow to a trickling filter be shut off before attempting to work on the filter?
15. What is a trend chart and how can it be used?
16. What should an operator do before an abnormal condition occurs?
17. How would you attempt to identify the source or cause of an abnormal condition?
18. Develop a *PLANT OPERATION PLAN* for when a surge of septic wastewater hits a treatment plant from the clearance of a sewer-line stoppage.

CHAPTER 6. TRICKLING FILTERS

(Lesson 3 of 3 Lessons)

6.7 LOADING CRITERIA

6.70 Typical Loading Rates

STANDARD-RATE FILTER:

Media (rock)	- 6 to 8 ft depth, growth sloughs periodically
Hydraulic Loading	- 25 to 100 gal/day/sq ft
Organic (BOD) Loading	- 5 to 25 lbs BOD/day/1000 cu ft

HIGH-RATE FILTER:

Media (rock)	- 3 to 5 ft depth, growth sloughs continually
Hydraulic Loading	- 100 to 1000 gal/day/sq ft
Organic (BOD) Loading	- 25 to 300 lbs BOD/day/1000 cu ft

6.71 Computing Hydraulic Loading

Hydraulic loading on a trickling filter is the amount of wastewater applied per day over the surface area of the media. This term also is called the hydraulic surface loading. In computing hydraulic loadings, several bits of information must be gathered. To figure the hydraulic loading, we must know:

1. The gallons per day applied to the filter, and
2. The surface area of the filter.

NOTE: Hydraulic loadings are expressed as:

gal/sq ft/day,[14] or
gal/day/sq ft = gpd/sq ft[14]

Both expressions mean the same. The hydraulic rate indicates the number of gallons of wastewater per day applied to each square foot of surface area or the gallons of water applied to each square foot each day.

Suppose we have a high-rate filter that is fed by a pump rated at 2100 gpm and the filter diameter is 100 feet.

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

For our problem, we must obtain the flow rate in gpd and surface area[15] in square feet or ft^2.

(a) Flow Rate, gpd

$$= 2100 \frac{\text{gal}}{\text{min}} \times \frac{60\text{ min}}{\text{hr}} \times \frac{24\text{ hrs}}{\text{day}}$$

$$= 3{,}024{,}000 \text{ gal/day}$$

(b) Surface Area, sq ft

$$= 0.785 \times (\text{Diameter, ft})^2$$

$$= 0.785 \times 100\text{ ft} \times 100\text{ ft}$$

$$= 7850\text{ sq ft}$$

(c) Hydraulic Loading, gpd/sq ft

$$= \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{3{,}024{,}000\text{ gpd}}{7850\text{ sq ft}}$$

$$= 385\text{ gpd/sq ft}$$

```
           385
7850) 3,024,000.
       2 355 0
       -------
         669 00
         628 00
         ------
          41 000
          39 250
          ------
           1 750
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[14] *Loadings as well as test results should always be presented using the same units. Theoretically a rate should have the* TIME UNIT LAST *(gal/sq ft/day); however, because flows are calculated as gal/day, it is easier to understand if loadings are reported as gal/day/sq ft.*

[15] *Area of a Circle, sq ft* $= 0.785 \times \text{Diameter, ft} \times \text{Diameter, ft}$, *or*

$= 0.785\ D^2$

Note that in computing hydraulic loadings when the filter effluent is recirculated to the filter influent, *RECIRCULATED* flow must be added to the primary clarifier effluent flow in order to calculate the total hydraulic loading. When filter effluent is recirculated to the primary clarifier influent, recirculated flow must be added to the clarifier influent flow.

6.72 Computing Organic (BOD) Loading

Using the same filter as in the above example of hydraulic loading, assume that the laboratory test results show that the wastewater being applied to the filter has a BOD of 100 mg/*L* and a filter depth of 3 feet. We need to know the pounds of BOD applied per day and the volume of the media in cu ft.

NOTE: Organic (BOD) loadings are expressed as:

lbs BOD/1000 cu ft/day, or

lbs BOD/day/1000 cu ft.

Both expressions mean the same. The organic loading indicates the pounds of BOD applied per day to the volume of filter media for treatment.

$$\text{Organic (BOD) Loading, lbs BOD/day/1000 cu ft} = \frac{\text{BOD Applied, lbs/day}}{\text{Volume of Media in 1000 cu ft}}$$

To solve this problem we must first calculate the BOD applied in lbs/day and volume of media in cu ft.

$$\begin{aligned}\text{Volume of Media, cu ft} &= \text{(Surface Area, sq ft) (Depth, ft)}\\ &= \text{(7850 sq ft) (3 ft)}\\ &= \text{23,550 cu ft}\end{aligned}$$

$$\begin{aligned}\text{Volume of Media, in 1000 cu ft} &= \text{23.5 (1000 cu ft units)}\\ &= \text{23.5 thousand cubic feet}\end{aligned}$$

$$\begin{aligned}\text{BOD Applied, lbs/day} &= \text{(BOD, mg/}L\text{) (Flow, MGD) (8.34 lb/gal)}^{16}\\ &= \frac{100\text{ mg}}{\text{M mg}} \times 3.024\,\frac{\text{M gal}}{\text{day}} \times \frac{8.34\text{ lb}}{\text{gal}}\\ &= \text{2522 lbs BOD/day}\end{aligned}$$

```
   3.024
    8.34
   12096
   9072
  24192
25.22016
```

$$\begin{aligned}\text{Organic BOD Loading, lbs BOD/day/1000 cu ft} &= \frac{\text{BOD Applied, lbs BOD/day}}{\text{Volume of Media (in 1000 cu ft)}}\\ &= \frac{\text{2522 lbs BOD/day}}{\text{23.5 (1000 cu ft)}}\\ &= \text{107 lbs BOD/day/1000 cu ft}\end{aligned}$$

```
        107.
23.5) 2522.0
      235
       172 0
       164 5
```

In computing BOD loadings, it is standard practice to ignore the BOD of the recirculated effluent, where recirculation is used. To attempt to perform this calculation (using the recirculated load) is complicated and makes it difficult to compare your loadings and resulting effluent quality with other plants.

If your plant must provide *NITRIFICATION*,[17] lower the organic loading to 20 to 30 pounds of BOD per day per 1000 cubic feet of filter media. This should produce an effluent with an ammonia nitrogen level below 1 mg/*L* and a nitrate-nitrogen concentration of around 15 mg/*L*.

6.73 Typical Loading Rates (Metric)

The next three sections show typical loading rates for trickling filters in the metric system and how to calculate the hydraulic loading and organic loading using the metric system.

STANDARD-RATE FILTER:

Media (rock)	- 1.8 to 2.4 meters depth
Hydraulic Loading	- 1.0 to 4.0 cu m/day/sq m
Organic (BOD) Loading	- 0.08 to 0.4 kg/day/cu m

HIGH-RATE FILTER:

Media (rock)	- 0.9 to 1.5 meters depth
Hydraulic Loading	- 4.0 to 40 cu m/day/sq m
Organic (BOD) Loading	- 0.4 to 4.8 kg/day/cu m

6.74 Computing Hydraulic Loading (Metric)

Suppose we have a high-rate filter that is fed by a pump rated at 0.132 cu m/sec (2100 gpm), and the filter diameter is 30.5 m (100 feet):

$$\text{Hydraulic Loading, cu m/day/sq m} = \frac{\text{Flow Rate, cu m/day}}{\text{Surface Area, sq m}}$$

For our problem, we must obtain the flow rate in cubic meters per day and the surface area in square meters.

(a) $$\begin{aligned}\text{Flow Rate, cu m/day} &= 0.132\,\frac{\text{cu m}}{\text{sec}} \times \frac{60\text{ sec}}{\text{min}} \times \frac{60\text{ min}}{\text{hr}} \times \frac{24\text{ hr}}{\text{day}}\\ &= \text{11,405 cu m/day}\end{aligned}$$

(b) $$\begin{aligned}\text{Surface Area, sq m} &= (0.785)\,(\text{Diameter, m})^2\\ &= 0.785 \times 30.5\text{ m} \times 30.5\text{ m}\\ &= \text{730.2 sq m}\end{aligned}$$

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[16] *The units of this formula can be proved by remembering that one liter weighs or equals one million milligrams.*

$$\frac{mg}{L} = \frac{mg}{1{,}000{,}000\ mg} = \frac{mg}{M\ mg}$$

Therefore,

$$\frac{mg}{L}\ BOD \times MGD \times 8.34\,\frac{lb}{gal} = \frac{mg\ BOD}{M\ mg} \times \frac{M\ gal}{day} \times \frac{lb}{gal} = lb\ BOD/day$$

[17] *Nitrification (NYE-tri-fi-KAY-shun). A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").*

(c)
$$\text{Hydraulic Loading, cu m/day/sq m} = \frac{\text{Flow Rate, cu m/day}}{\text{Surface Area, sq m}}$$

$$= \frac{11{,}405 \text{ cu m/day}}{730.2 \text{ sq m}}$$

$$= 15.7 \text{ cu m/day/sq m}$$

$$\text{or} \quad = 385 \text{ gpd/sq ft}$$

6.75 Computing Organic (BOD) Loading (Metric)

Using the same filter as in the above example of hydraulic loading, assume that the laboratory test results show that the wastewater being applied to the filter has a BOD of 100 mg/*L*. We need to know the kilograms of BOD applied per day and the volume of the media in cubic meters.

$$\frac{\text{Organic (BOD) Loading, kg BOD/day}}{\text{cu m}} = \frac{\text{Bod applied, kg/day}}{\text{Volume of media in cu m}}$$

To solve this problem we must first calculate the volume of the media in cubic meters and the BOD applied in kilograms per day.

$$\text{Volume of Media, cu m} = (\text{Surface Area, sq m})\,(\text{Depth, m})$$

$$= (730.6 \text{ sq m})(0.9 \text{ m})$$

$$= 657.5 \text{ cu m}$$

$$\text{BOD Applied, kg/day} = (\text{BOD, mg}/L)\,(\text{Flow, cu m/day})\,(1000 \text{ kg/cu m})^{18}$$

$$= \frac{100 \text{ mg}}{1{,}000{,}000 \text{ mg}} \times \frac{11{,}447 \text{ cu m}}{\text{day}} \times \frac{1{,}000 \text{ kg}}{\text{cu m}}$$

$$= 1{,}144.7 \text{ kg/day}$$

$$\frac{\text{Organic BOD Loading, kg BOD/day}}{\text{cu m}} = \frac{\text{BOD Applied, kg BOD/day}}{\text{Volume of Media, cu m}}$$

$$= \frac{1{,}144.7 \text{ kg BOD/day}}{657.5 \text{ cu m}}$$

$$= 1.7 \text{ kg BOD/day/cu m}$$

$$\text{or} \quad = 107 \text{ lbs BOD/day/1000 cu ft}$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 190 and 191.

6.7A What is hydraulic loading of a trickling filter and how is it expressed?

6.7B What information must be available to figure the hydraulic loading on a trickling filter?

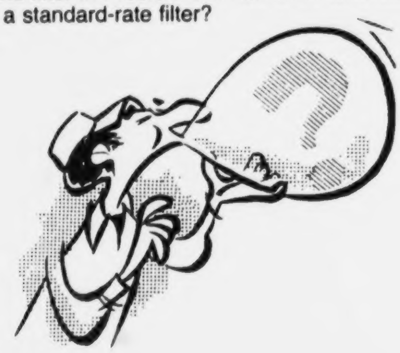
6.7C What is the hydraulic loading on a trickling filter 80 feet in diameter that is receiving a flow of 3200 gpm?

6.7D Is the filter in Problem 6.7C within the normal hydraulic loading range for high-rate filters?

6.7E What information is needed to figure the BOD loading on a trickling filter?

6.7F Compute the BOD loading on a standard-rate trickling filter with a diameter of 100 feet, media depth 8 feet, which is receiving 350 gpm of wastewater with a BOD of 100 mg/*L*.

6.7G Is the filter in Problem 6.7F loaded within normal limits for a standard-rate filter?



6.8 TRICKLING FILTER/SOLIDS CONTACT (TF/SC) PROCESS

A modification of the trickling filter process is the trickling filter/solids contact process. Final effluent from trickling filters passes through an aerated solids contact tank (similar to the activated sludge aeration tanks shown in Figures 8.2 and 8.4 on pages 236 and 238 and then through secondary clarifiers with flocculator center wells. The sludge from the secondary clarifiers is mixed with trickling filter effluent and the mixture flows through the aeration solids contact tank. Excess secondary clarifier sludge (return sludge) is treated by the same methods as secondary clarifier sludge from trickling filter plants.

This process reliably and economically produces an effluent of much better quality (low BOD and suspended solids) than effluent produced by trickling filters alone. The aerated solids contact time (detention time) is one hour or less based on total flow, including recycle or return sludge flow. The solids retention time or sludge age (see page 241) of the aerated solids contact tank is less than two days. The mixed liquor suspended solids (MLSS, see Chapter 11, "Activated Sludge," Volume II) in the aeration contact tank can range from 1000 to 2500 mg/*L* and have little effect on the final effluent suspended solids. For additional information, see "Full-Scale Studies of the Trickling Filter/Solids Contact Process," by R.N. Matasci, C. Kaempfer and J.A. Heidman, *Journal Water Pollution Control Federation*, Volume 58, Number 11, November 1986, pages 1043 to 1049.

6.9 REVIEW OF PLANS AND SPECIFICATIONS

Plans and specifications should be reviewed by operators so they can:

1. Become familiar with a proposed plant,
2. Learn what will be constructed, and
3. Offer suggestions on how the plant can be designed for easier and more effective operation and maintenance.

When reviewing plans, carefully study those areas influencing how the plant will be operated and maintained. These areas should include:

1. Site.
   a. Access to the filter. Consider roads for maintenance equipment and walkways for personnel.
   b. Overhead clearance. Determine locations and distances to electrical power and telephone lines. Be sure

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[18] *The density of water is 1000 kg per cu m. Also remember that 1 liter of water weighs 1,000,000 mg.*

they will not interfere with the boom of a crane lifting a turntable.

   c. Trees and shrubs near filters. Trees should not be planted or allowed to remain close to open filters because leaves will plug the voids in the media, cause ponding, and also prevent ventilation. Evergreen trees are recommended over trees that lose their leaves. Be sure that trees are planted where their roots can't get into plant piping.

   d. Location of hose bibs (high-pressure water faucets). Place hose bibs at convenient locations for washing down the filter and other maintenance jobs.

2. Trickling filter structure.

   a. Access to turntable seals and also oil drain, fill and level plugs. Be sure sufficient space is provided for necessary maintenance work.

   b. Layout of underdrain grillage and channels. Space must be provided for flushing out solids, carrying solids away, and also proper ventilation.

   c. Location of valves and gates. Provisions must be made to allow flooding of the filter media and also dewatering of effluent control boxes and underdrain collector channels. Be sure valves are located between observation and sampling manholes and the filter in order to allow flooding of the filter.

   d. Access to effluent boxes. Access and space must be available for removal of effluent box covers or grates and also maintenance of slide gates.

   e. Center column support. Support should be wide enough for timbers and jacks to be used to raise the distributor from the turntable for race maintenance.

   f. Covered trickling filters.

      1) The operator cannot easily see if the distributor arm is moving under the cover. Some type of device which causes a light to flash when the arm passes a certain point should be placed on the end of one of the arms. Then the operator can determine the speed of rotation of the distributor arm by watching the flashing light.

      2) If the filter is completely covered, a forced-air ventilation system is needed. If odors cause complaints from neighbors, an odor-scrubbing device will be needed also. The fans should be installed so the forced-air ventilation will be in the same direction as natural air currents. These ventilation fans must be equipped with air-tight seals to avoid corrosion problems.

      3) Proper materials must be used to avoid corrosion of the roof structure.

3. Equipment.

   a. Distributors

      1) Adjustable orifice plates should be installed on both the leading and trailing edges of the distributor arms.

      2) Safety stops should be installed to prevent endgate handle from catching in the media during flushing of the distributor arm.

      3) Turnbuckles on guy rods must have sufficient thread length to make necessary adjustments.

   b. Valves

      1) Valves must seat properly against design heads to prevent leakage back into channel during dewatering operations.

      2) A protective coating must be applied to all gates and frames.

      3) Stop nuts must be installed on all valve stems.

4. Safety

   a. Guardrails must be located where necessary.

   b. Look for areas where splashing water could cause slippery surface and suggest corrective changes.

   c. Be sure switches for turning off pumps to distributor arms are located so that the distributor arm can be stopped quickly and easily when necessary.

   d. Install 115 to 120-volt receptacles at appropriate locations to permit the use of drop lights when inspecting vents and underdrains.

NOTE: Some items may not be covered on the plans, but may be discussed in the specifications.

When reading specifications, study the following items:

1. Equipment details should indicate the sizes, capacities, flow rates, pressures, horsepowers, efficiencies and materials. Be sure protective guards and coatings are provided.

2. Performance capabilities of equipment.

3. Testing details. Will the equipment be tested at the manufacturer's factory and/or at the plant site? What are the tests supposed to accomplish?

4. Responsibility of equipment manufacturer's representative regarding:

   a. Installation inspection,

   b. Installation testing,

   c. Training of staff for equipment operation and maintenance,

   d. Assistance during start-up, and

   e. Warranty period and conditions.

5. Number of copies of prints, O & M manuals, and manufacturer's service manuals.

6. Lists of equipment spare parts (including serial and/or stock numbers) and quantity of each spare part that should be provided.

7. Safety

   a. Safety equipment provided to protect operators.

   b. Equipment has necessary approvals of safety agencies.

6.10 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read all of Section A.6, Force, Pressure and Head.

In Section A.13, Typical Wastewater Treatment Plant Problems, read and work the problems in Section A.133, Trickling Filters.

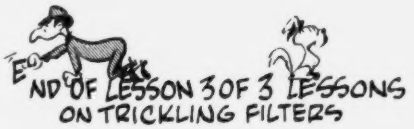
6.11 ADDITIONAL READING

1. *MOP 11*, Chapter 9, "Trickling Filtration."
2. *NEW YORK MANUAL*, Chapter 5,* "Secondary Treatment."
3. *TEXAS MANUAL*, Chapter 12, "Trickling Filters."
4. *PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES* (EPA 430/9-77-006, March 1977). Obtain from Environmental Quality, Instructional Resource Center, Room 310, 1200 Chambers Road, Columbus, Ohio 43212. Order No. 014U, price $12.64.
5. *TRICKLING FILTER MANUAL*, prepared by Minnesota Pollution Control Agency. Available from National Environmental Training Association, 8687 Via de Ventura, Suite 214, Scottsdale, AZ 85258. Price, members, $17.50, nonmembers, $22.50.

* Depends on edition.

6.11 METRIC CALCULATIONS

Refer to Sections 6.73, 6.74 and 6.75 for the solutions to all problems in this chapter using metric calculations.


END OF LESSON 3 OF 3 LESSONS
ON TRICKLING FILTERS

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 3 Lessons)

Chapter 6. TRICKLING FILTERS

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 2.

A trickling filter is 70 feet in diameter and the depth of the media is 5 feet. The average daily flow is 2450 gpm and the BOD of the influent to the filter is 100 mg/*L*. Show your work and calculate:

19. Flow in gallons per day.
20. Surface area of filter.
21. Hydraulic surface loading.
22. BOD applied in pounds per day.
23. Volume of filter media.
24. Organic loading.

PLEASE WORK THE OBJECTIVE TEST NEXT.

SUGGESTED ANSWERS

Chapter 6. TRICKLING FILTERS

Answers to questions on page 167.

6.0A (a) settleable solids and (b) scum or floatable solids. (c) BOD, or organic material, or oxygen-demanding material.

6.0B The purpose of secondary treatment is to remove soluble and nonsettleable (or nonfloating) oxygen-demanding substances.

6.0C The trickling filter process works by distributing settled wastewater over the filter media. Microorganisms grow on the filter media and convert colloidal and soluble oxygen-demanding substances to forms that will separate from the wastewater being treated.

6.0D The distributor arms or pipes on a trickling filter rotate because of the reaction from the force of the water leaving the arms (as with a lawn sprinkler or fire hose), or by mechanical means (a motor and gears).

6.0E Recirculation increases the efficiency of a trickling filter by increasing the time of contact of the wastewater with the biological slime growth on the filter media, and by washing off excess growths (sloughing). Sloughing keeps the biological film in an aerobic condition and seeds the lower regions of the filter with active organisms. Sometimes recirculation is used to prevent intermittent drying of slimes on the filter media.

Answers to questions on page 169.

6.1A The three general classifications of trickling filters are standard-rate, high-rate, and roughing filters.

6.1B The principal differences between standard-rate and high-rate filters include BOD loadings, hydraulic loadings, depth of the media, recirculation and effluent quality.

Answers to questions on page 170.

6.2A Items that should be checked before placing a filter in service:

☐ Check type and amount of oil used in all oil reservoirs.
☐ Examine distributor arms for rotation and level.
☐ Inspect distributor orifices.
☐ Remove debris from underdrain system.
☐ Touch up any damage to painted surfaces.
☐ Examine valves for seating and smooth operation.
☐ Remove any trash on or in the media.

6.2B During start-up heavy chlorination is necessary to reduce the health hazard and the pollutional load in the receiving waters because the slime growths have not developed on the filter media.

6.2C Items requiring daily checking:

☐ Ponding
☐ Filter flies
☐ Odors
☐ Plugged orifices
☐ Roughness or vibration of distributor arms
☐ Leakage past the seal
☐ Splash beyond the filter media
☐ Cleanup of slimes not on media

6.2D If a clarifier is operated below design hydraulic loading, the solids in the clarifier will become septic and cause a poor effluent. When the hydraulic loading is too high, some solids may be washed out of the clarifier.

Answers to questions on page 171.

6.2E Before shutting down a trickling filter or any other major plant process or piece of equipment, always take a few minutes to plan what you are going to do.

6.2F The following items should be considered when shutting down a trickling filter:

1. Incoming flow rates.
2. How will shutdown affect rest of plant?
3. Are the necessary tools and other needed items available? and
4. Are there any other tasks that should be performed while the filter is off the line?

Answers to questions on page 172.

6.3A To determine if the distribution of wastewater over the trickling filter is even, place pans of the same size in the media at several points along the radius of the filter. Run the distributor until the pans are almost full. The amount of water in each pan should not vary from the average by more than 5 percent.

6.3B Laboratory tests used to measure the efficiency of a trickling filter include BOD, suspended solids, and settleable solids.

6.3C (1) Plant Efficiency:

$$\text{BOD Efficiency, \%} = \frac{(\text{In - Out})}{\text{In}} \times 100\%$$

$$= \frac{(200 \text{ mg}/L - 20 \text{ mg}/L)}{200 \text{ mg}/L} \times 100\%$$

$$= 90\%$$

(2) Trickling Filter Efficiency:

$$\text{Trickling Filter Efficiency, \%} = \frac{(\text{In - Out})}{\text{In}} \times 100\%$$

$$= \frac{(140 \text{ mg}/L - 20 \text{ mg}/L)}{140 \text{ mg}/L} \times 100\%$$

$$= 85.7\%$$

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 174.

6.4A The major consideration for daily operation of a trickling filter is to use the lowest recirculation rates that will produce good results (meet NPDES permit requirements), but not cause ponding or other problems.

6.4B Trickling-filter effluent should be from *1.5* to *2.0* mg/*L* DO.

Answers to questions on page 177.

6.4C Causes of ponding include excessive organic loadings without corresponding high recirculation rate, media too small or not sufficiently uniform in size, accumulation of debris in filter spaces (voids), or an excessive growth of insect larvae or snails.

6.4D To correct a ponding problem:

(a) Locate cause.
(b) Increase hydraulic loading by increasing recirculation.
(c) Adjust distributor so it will rotate more slowly and flush off some of the slime.
(d) If media are non-uniform, they should be replaced.
(e) Spray filter surface with a high-pressure water stream or stop distributor and allow it to flush problem area.
(f) Rake or turn ponding area.
(g) Shut off filter for a few hours and allow growth to dry so part of it may be flushed out.
(h) Flood filter.
(i) Dose filter with chlorine.

There are many possible ways to correct ponding. The approach for a particular problem should be aimed at the cause and the quickest and easiest way to correct the situation. You are not expected to have listed all the answers, but to know some of them.

6.4E To correct an odor problem in a trickling filter:

(a) Maintain aerobic conditions in collection system and primary units.
(b) Maintain ventilation in filter.
(c) Increase recirculation rate if odor problems develop.

6.4F Trickling filter flies can be controlled by:

(a) Increasing recirculation.
(b) Flooding filter weekly.
(c) Carefully applying insecticides.
(d) Cleaning around the filter, including pruning grass and shrubbery.

6.4G A trickling filter should not be taken out of service during icing conditions because the quality of the effluent will be reduced and additional maintenance problems could develop.

Answers to questions on page 181.

6.4H Four possible sources of abnormal conditions include:

1. Storm water infiltration;
2. Broken collection system pipe that permits excess inflow from groundwater, a creek or stream;
3. Clearance of a main line sewer stoppage; and
4. Industrial discharges.

6.4I During excess flows, the operator can make the following adjustments to the trickling-filter process:

1. If possible, increase the number of filters in operation. Filters should have active slime growths on media;
2. Reduce or stop filter recycle or recirculation; and
3. Operate filters in parallel rather than in series.

6.4J High flows from the clearance of a sewer stoppage contain a septic, odorous influent with a high solids and BOD load, but flows from a broken pipe may not be septic or have the other problems.

6.4K Toxic industrial discharges are difficult to detect because:

(1) The plant influent is usually not monitored for the toxic substance or condition (high or low pH), and (2) industry may not notify the operator when a toxic spill or dump occurs.

6.4L Toxic industrial discharges are often detected or suspected when excessive amounts of solids start appearing in the plant effluent, indicating that something has upset the organisms living in the slime growths on the trickling filter.

6.4M When attempting to correct a trickling filter problem, make only one change at a time and wait approximately one week to allow the organisms (biological process) to stabilize so you can evaluate the effectiveness of each change.

Answers to questions on page 183.

6.5A The purpose of the seal is to prevent wastewater leakage from the center column before the wastewater is distributed over the media.

6.5B Some oil should be drained from the distributor each time it is checked to examine the condition of the oil and to be sure the oil level sensing line is not plugged.

6.5C The rotational speed of a distributor can be reduced by opening orifices on the front side of the distributor arms.

6.5D Trickling-filter underdrain maintenance consists of flushing the lines or channels to remove sludge deposits or debris every 3 to 6 months.

Answers to questions on page 183.

6.6A Flow to a trickling filter should be shut off before attempting to work on a filter because the rotating arms can cause serious injury.

6.6B Walk carefully on the filter media because the slime growths on the media are very slippery.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 186.

6.7A Hydraulic loading on a trickling filter is the amount of wastewater applied per day over the surface area, expressed as gallons/day/sq ft, or gpd/sq ft.

6.7B Gallons per day applied to the filter and surface area of the filter in sq ft. These two items are all that are needed. However, it is necessary to convert the other data into the proper form (gpm to gal/day and surface area to sq ft).

6.7C *GIVEN:* Diameter = 80 ft
Flow = 3200 gpm

REQUIRED: Hydraulic Loading

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

Find *FLOW RATE,* gpd, and *SURFACE AREA* in sq ft.

$$\text{Flow Rate, gpd} = 3200\,\frac{\text{gal}}{\text{min}} \times \frac{60\text{ min}}{\text{hr}} \times \frac{24\text{ hrs}}{\text{day}}$$

$$= 4{,}608{,}000\text{ gal/day}$$

$$\text{Surface Area, sq ft} = 0.785 \times (\text{Diameter, ft})^2$$

$$= 0.785 \times 80\text{ ft} \times 80\text{ ft}$$

$$= 5025\text{ sq ft (rounded off)}$$

$$\text{Hydraulic Loading gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{4{,}608{,}000\text{ gpd}}{5025\text{ sq ft}}$$

$$= 917\text{ gpd/sq ft}$$

6.7D Yes. The hydraulic loading range for high-rate filters is 100 to 1000 gpd/sq ft.

6.7E To calculate the BOD loading on a trickling filter, the pounds of BOD applied per day and the volume of filter media in thousands of cu ft are needed. Since BOD is reported in mg/*L*, the standard formula for converting mg/*L* to pounds per day is needed (mg/*L* × MGD × 8.34), and usually gpm will have to be converted to MGD (700 gpm = 1 MGD). There are many conversion factors that can be used to obtain the correct answers, and you should use the ones you are familiar with and understand.

6.7F *GIVEN:* Diameter = 100 ft
Depth = 8 ft
Flow = 350 gpm
BOD = 100 mg/*L*

REQUIRED: Organic (BOD) Loading

$$\text{Organic (BOD) Loading, lbs BOD/day/1000 cu ft} = \frac{\text{BOD Applied, lbs (BOD/day}}{\text{Volume of Media, 1000 cu ft}}$$

Find *SURFACE AREA, MEDIA VOLUME,* and *BOD APPLIED.*

$$\text{Surface Area, sq ft} = 0.785 \times (\text{Diameter, ft})^2$$

$$= 0.785 \times 100\text{ ft} \times 100\text{ ft}$$

$$= 7{,}850\text{ sq ft}$$

$$\text{Volume of Media, cu ft} = (\text{Surface Area, sq ft})(\text{Depth, ft})$$

$$= (7{,}850\text{ sq ft})(8\text{ ft})$$

$$= 62{,}800\text{ cu ft}$$

$$= 62.8\ (1000\text{ cu ft})$$

$$\text{Flow Rate, MGD} = \frac{(350 \text{ gpm})}{700 \text{ gpm/MGD}}$$

$$= 0.5 \text{ MGD}$$

$$\text{BOD Applied, lbs/day} = (\text{BOD, mg}/L)\,(\text{Flow, MGD})\,(8.34 \text{ lb/gal})$$

$$= 100 \frac{\text{mg}}{\text{M mg}} \times 0.5 \frac{\text{M gal}}{\text{day}} \times 8.34 \frac{\text{lb}}{\text{gal}}$$

$$= 417 \text{ lbs BOD/day}$$

$$\text{Organic (BOD) Loading, lbs/day/1000 cu ft} = \frac{\text{BOD Applied, lbs/day}}{\text{Volume of Media, 1000 cu ft}}$$

$$= \frac{417 \text{ lbs/day}}{62.8 \text{ (1000 cu ft)}}$$

$$= 6.6 \text{ lbs BOD/day/1000 cu ft}$$

6.7G Yes. The BOD loading range for standard-rate filters is 5 to 25 pounds of BOD per day per 1000 cu ft.

END OF ANSWERS TO QUESTIONS IN LESSON 3

OBJECTIVE TEST

Chapter 6. TRICKLING FILTERS

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one answer to each question.

1. Trickling filtration is a primary treatment process.
   1. True
   2. False

2. Trickling filters are sometimes called biofilters.
   1. True
   2. False

3. Screening and flotation are biological methods of treating wastewater.
   1. True
   2. False

4. Disinfection is done in trickling filters.
   1. True
   2. False

5. Masking agents are used to cover trickling filter media.
   1. True
   2. False

6. Primary clarifier effluent is the same as trickling filter influent in some treatment plants.
   1. True
   2. False

7. Trickling filter efficiency is not influenced by temperature.
   1. True
   2. False

8. Odors can be an indication of how poorly or properly a trickling filter is operating.
   1. True
   2. False

9. What may happen if wastewater recirculation rates are too low?
   1. Aerobic conditions may develop in the secondary clarifier.
   2. Anaerobic conditions may develop in the secondary clarifier.

10. What might happen if recirculation rates are too high?
    1. Solids will wash out of the secondary clarifier.
    2. The effluent will be sparkling clear.

11. A flow of 2100 GPM is approximately the same as
    1. 0.33 MGD.
    2. 0.50 MGD.
    3. 1.0 MGD.
    4. 2 MGD.
    5. 3 MGD.

12. Physical methods of waste treatment include
    1. Activated sludge.
    2. Disinfection.
    3. Screens.
    4. Sedimentation.
    5. Trickling filters.

13. The differences between high-rate filters and standard-rate filters include
    1. Depth of filter.
    2. Flows per day per square foot of surface area.
    3. Pounds of BOD per day per cubic foot of media.
    4. Type of distributor.
    5. Type of rock.

14. The basic parts of a trickling filter include
    1. Distribution box.
    2. Distribution system.
    3. Media.
    4. Pumps.
    5. Underdrain system.

15. Before starting up a new trickling filter plant, the operator should check the
    1. Filter media to be sure it consists of rocks of different sizes packed tightly together.
    2. Oil reservoirs for proper amount and type of oil.
    3. Rotation of distributor arm.
    4. Underdrain system for debris.
    5. Zoogleal film on filter media.

16. When operating a trickling filter, the operator should
    1. Adjust the process to obtain the best possible results for the least cost.
    2. Bubble oxygen up through the filter.
    3. Maintain aerobic conditions in the filter.
    4. Rotate the distributor as fast as possible to better spray settled wastewater over the media.
    5. Use the lowest recirculation rates that will yield good results to conserve power.

17. Successful trickling filter operation depends on
    1. Filtering the solids out of the wastewater.
    2. Maintenance of a chlorine residual in the effluent.
    3. Maintenance of a good growth of organisms on the filter media.
    4. Preventing sludge bulking.
    5. Washing all slimes off the filter media.

18. Problems associated with trickling filters include
    1. Bulking.
    2. Filter flies.
    3. Odors.
    4. Ponding.
    5. Turbid effluent.

19. To correct an odor problem in a trickling filter, the operator should
    1. Check ventilation in the filter.
    2. Increase recirculation rate.
    3. Shut off flow to the filter.
    4. Take corrective action immediately.
    5. Try to develop and maintain aerobic conditions.

20. Ponding on a trickling filter may be caused by
    1. Dosing the filter with chlorine.
    2. Excessive organic loading.
    3. Insufficient recirculation rate.
    4. Spraying (jetting) the filter surface with a high-pressure water stream.
    5. Use of media which are too small.

21. Which test *BEST* measures the efficiency of a trickling filter?
    1. BOD
    2. pH
    3. Sludge age
    4. Temperature
    5. Total solids

22. Masking agents
    1. Are biological agents.
    2. Cover the filter.
    3. Mask the plant.
    4. May be sprayed into the air.
    5. Tend to make undesirable odors less noticeable.

23. A shock load is
    1. An earthquake.
    2. An electrical charge.
    3. A heavy blow.
    4. An unexpected strong influent flow.
    5. A waste which is toxic to plant organisms.

24. Loadings on a trickling filter may be expressed as
    1. gal/day/sq ft.
    2. gal/day/1000 cu ft.
    3. lb BOD/day/sq ft
    4. lb BOD/day/1000 cu ft
    5. lb H_2O/day/sq ft

25. The hydraulic surface loading on a trickling filter 80 feet in diameter with a flow of 0.5 MGD is approximately
    1. 100 gpd/sq ft.
    2. 95 gpd/sq ft.
    3. 90 gpd/sq ft.
    4. 85 gpd/sq ft.
    5. 80 gpd/sq ft.

26. What is the organic load applied to a trickling filter in pounds of BOD per day for a filter with a diameter of 80 feet, a depth of 4 feet, a flow of 0.5 MGD, and a filter influent BOD of 100 mg/*L*?
    1. 20 lbs/day
    2. 150 lbs/day
    3. 335 lbs/day
    4. 350 lbs/day
    5. 417 lbs/day

27. Maintenance of a distributor moved by hydraulic action includes
    1. Adjusting the end gates if the distributor arm does not rotate smoothly.
    2. Adjusting turnbuckles occasionally on guy rods to keep rotating arms at proper level.
    3. Cleaning orifices in the distributor arms.
    4. Cleaning the filter media.
    5. Greasing gears that rotate the distributor.

28. The following information is provided regarding a trickling filter:
    a. Media is uniformly sized and not disintegrating,
    b. Media surface is free of debris,
    c. Organic loadings have increased recently, and
    d. Hydraulic loadings have remained constant.

    What could be the cause of ponding on the trickling filter?
    1. Increase in biological slime growths on media.
    2. Increase in chlorination dose to the filter.
    3. Increase in filter ventilation.
    4. Increase in growths of pathogenic organisms in the filter voids.
    5. Increase in wastewater distribution over the surface of the media.

END OF OBJECTIVE TEST

APPENDIX

(Monthly Data Sheet)

CLEANWATER, U.S.A.

WATER POLLUTION CONTROL PLANT

MONTHLY RECORD ________ 19 ___

OPERATOR: ________________

				RAW WASTEWATER					PRIM. EFF.			FINAL EFFLUENT					DIGESTION					REMARKS
DATE	DAY	WEATHER	FLOW MGD	TEMP.	pH	SETT. SOLIDS	BOD	SUSP. SOLIDS	BOD	SUSP. SOLIDS	D.O.	pH	BOD	SUSP. SOLIDS	D.O.	CL_2 RES.	RAW SLUDGE GALS/DAY	SCUM GALS/DAY	% CO_2	GAS PROD. FT^3/DAY	MIXING HRS.	
1	M	FAIR	1.200	70	7.3	8	190	208	132	95	2.3	7.6	29	21	7.0	2.1	5940	100	32	10800	4	
2	T	"	1.091	69	7.2	10	205	218	143	101	1.9	7.4	31	24	6.8	2.4	5135	110	32	11450	–	
3	W	"	1.120	69	7.3	11	220	222	153	108	2.0	7.0	23	26	5.9	3.0	5380	90	33	11220	8	
4	T	"	0.987	70	7.1	9	184	201	127	92	2.1	7.2	28	32	6.3	1.8	4765	120	33	11570	8	SLUDGE TO #1 BED – 16,000 GAL.
5	F	CLDY	1.008	68	7.0	7	232	248	162	120	2.0	7.3	31	25	8.1	1.9	5010	115	34	10990	8	
6	S	"	1.102	68	7.2	9	211	210	147	105	2.2	7.3	30	30	7.8	2.1	5240	120	32	11200	4	
7	S	FAIR	0.974	69	7.3	8	199	215	139	98	2.1	7.2	26	29	7.4	2.0	4895	110	32	12100	4	
8																						
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26																						
27																						
28																						
29																						
30																						
31																						
MAX.																						
MIN.																						
AVG.			1.016	69	7.1	9	195	210	130	100	2.0	7.3	30	27	6.4	2.0	4980	100	33	11,000	4	

SUMMARY DATA

% REMOVAL	BOD	SS
INF–PRI	30.0	52.4
INF–EFF	84.6	87.2

SLUDGE DATA

% SOLIDS — AVG.	4.4
LBS. DRY SOLIDS / DAY	1,827
% VOL. SOLIDS — AVG.	76
LBS. VOL. SOLIDS / DAY	1,388
LBS. VOL. SOLIDS / 1000 FT^3/DAY	27.7
GALS. SLUDGE TO BEDS	48,000
CU. YDS. CAKE REMOVED	22
FT^3 GAS / LB. VOL. SOLIDS	8.0
FT^3 GAS / MG FLOW	10,800

COST DATA

MAN DAYS 44 PAYROLL	$ 1,250—
POWER PURCHASED	450—
OTHER UTILITIES (GAS, H_2O)	60—
GASOLINE, OIL, GREASE	30—
CHEMICALS AND SUPPLIES	95—
MAINTENANCE	140—
VEHICLE COSTS	70—
OTHER	20—
TOTAL	$ 2,105—
OPERATING COST/MG TREATED	$ 66.83
OPERATING COST/CAPITA / MO.	$ 0.21

FLOW METER:
LAST 445237
1st 413749
TOTAL: 31.488 MG

ELECTRIC METER:
LAST 5196
1st 4821
MULT 80 x 375 = 30,000 KWH

RAW SLUDGE:
LAST 857,314
1st 699,814
STROKES — SCUM 3100
TOTAL: 154,000 x 1.0 = 154,000 GALS

GAS METER:
LAST 724296
1st 383296
TOTAL: 341,000 FT^3

CHAPTER 7

ROTATING BIOLOGICAL CONTACTORS

by

Richard Wick

TABLE OF CONTENTS

Chapter 7. Rotating Biological Contactors

Page

OBJECTIVES 198
GLOSSARY 199
7.0 Description of Rotating Biological Contactors 200
7.1 Process Operation 208
  7.10 Pretreatment Requirements 208
  7.11 Start-Up 208
    7.110 Pre-Start Checks for New Equipment 208
    7.111 Procedure for Starting Unit 211
  7.12 Operation 211
    7.120 Inspecting Equipment 211
    7.121 Testing Influent and Effluent 212
    7.122 Observing the Media 214
  7.13 Abnormal Operation 216
  7.14 Shutdown and Restart 216
7.2 Maintenance 216
  7.20 Break-In Maintenance 216
  7.21 Preventive Maintenance Program 217
  7.22 Housekeeping 217
  7.23 Troubleshooting Guide 218
    7.230 Roller Chain Drive 218
    7.231 Belt Drive 219
7.3 Safety 220
  7.30 Slow-Moving Equipment 220
  7.31 Wiring and Connections 220
  7.32 Slippery Surfaces 220
  7.33 Infections and Diseases 220
7.4 Review of Plans and Specifications 220
7.5 Loading Calculations 220
  7.50 Typical Loading Rates 220
  7.51 Computing Hydraulic Loading 220

7.52 Computing Organic (BOD) Loading 221
7.53 Typical Loading Rates (Metric) 221
7.54 Computing Hydraulic Loading (Metric) 221
7.55 Computing Organic (BOD) Loading (Metric) 221
7.6 Arithmetic Assignment 222
7.7 Acknowledgments 222
7.8 Additional Reading on Rotating Biological Contactors 222
7.9 Metric Calculations 222

OBJECTIVES

Chapter 7. ROTATING BIOLOGICAL CONTACTORS

Following completion of Chapter 7, you should be able to do the following:

1. Describe a rotating biological contactor and the purpose of each important part,
2. Start-up and operate a rotating biological contactor,
3. Operate a rotating biological contactor under abnormal conditions,
4. Shutdown and restart a rotating biological contactor,
5. Maintain and troubleshoot a rotating biological contactor,
6. Safely perform the duties of the operator of a rotating biological contactor,
7. Review the plans and specifications for a rotating biological contactor, and
8. Calculate the hydraulic and organic loadings on a rotating biological contactor.

GLOSSARY

Chapter 7. ROTATING BIOLOGICAL CONTACTORS

BIODEGRADABLE (BUY-o-dee-GRADE-able) BIODEGRADABLE

Organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odors.

COMPOSITE (PROPORTIONAL) SAMPLE (com-POZ-it) COMPOSITE (PROPORTIONAL) SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

GRAB SAMPLE GRAB SAMPLE

A single sample of wastewater taken at neither a set time nor flow.

INHIBITORY SUBSTANCES INHIBITORY SUBSTANCES

Materials that kill or restrict the ability of organisms to treat wastes.

MPN (EM-PEA-EN) MPN

MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume. Expressed as a density or population of organisms per 100 ml.

NEUTRALIZATION (new-trall-i-ZAY-shun) NEUTRALIZATION

Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.

NITRIFICATION (NYE-tri-fi-KAY-shun) NITRIFICATION

A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

PYROMETER (pie-ROM-uh-ter) PYROMETER

An apparatus used to measure high temperatures.

SOLUBLE BOD SOLUBLE BOD

Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.

SUPERNATANT (sue-per-NAY-tent) SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.

CHAPTER 7. ROTATING BIOLOGICAL CONTACTORS

7.0 DESCRIPTION OF ROTATING BIOLOGICAL CONTACTORS

Rotating biological contactors (RBC) are a secondary biological treatment process (Figure 7.1) for domestic and *BIODEGRADABLE*[1] industrial wastes. Biological contactors have a rotating "shaft" surrounded by plastic discs called the "media." The shaft and media are called the "drum" (Figures 7.2 and 7.3). A biological slime grows on the media when conditions are suitable. This process is very similar to a trickling filter where the biological slime grows on rock or other media and settled wastewater (primary clarifier effluent) is applied over the media. With rotating biological contactors, the biological slime grows on the surface of the plastic-disc media. The slime is rotated into the settled wastewater and then into the atmosphere to provide oxygen for the organisms (Fig. 7.2). The wastewater being treated usually flows parallel to the rotating shaft, but may flow perpendicular to the shaft as it flows from stage-to-stage or tank-to-tank.

The plastic-disc media are made of high-density plastic circular sheets usually 12 feet (3.6 m) in diameter. These sheets are bonded and assembled onto horizontal shafts up to 25 feet (7.5 m) in length. Spacing between the sheets provides the hollow (void) space for distribution of wastewater and air (Figures 7.3 and 7.4).

The rotating biological contactor process uses several plastic media drums. Concrete or coated steel tanks usually hold the wastewater being treated. The media rotate while approximately 40 percent of the media surface is immersed in the wastewater (Fig. 7.4). As the drum rotates, the media pick up a thin layer of wastewater which flows over the biological slimes on the discs. Organisms living in the slimes use organic matter from the wastewater for food and dissolved oxygen from the air, thus removing wastes from the water being treated. As the attached slimes pass through the wastewater, some of the slimes are sloughed from the media as the media rotates downward into the wastewater being treated. The effluent with the sloughed slimes flows to the secondary clarifier where the slimes are removed from the effluent by settling. Figure 7.5 shows the location of a rotating biological contactor process in a wastewater treatment plant. The process is located in the same position as the trickling filter or activated sludge aeration basin. Usually the process operates on a "once-through" scheme, with no recycling of effluent or sludge, which makes it a simple process to operate.

The major parts of the process are listed in Table 7.1 along with their purposes. The concrete or steel tanks are commonly shaped to conform to the general shape of the media. This shape eliminates dead spots where solids could settle out and cause odors and septic conditions. These tanks may be divided into four bays (stages) with either concrete walls or removable baffles, depending on the design.

The rotating biological contactor process is usually divided into four different stages (Fig. 7.6). Each stage is separated by a removable baffle, concrete wall or cross-tank bulkhead. Wastewater flow commonly is parallel to the shaft. Each bulkhead or baffle has an underwater orifice or hole to permit flow from one stage to the next. Each section of media between bulkheads acts as a separate stage of treatment.

Staging is used in order to maximize the effectiveness of a given amount of media surface area. Organisms on the first-stage media are exposed to high levels of BOD and reduce the BOD at a high rate. As the BOD levels decrease from stage to stage, the rate at which the organisms can remove BOD decreases.

Treatment plants requiring four or more shafts of media usually are arranged so that each shaft serves as an individual stage of treatment. The shafts are arranged so the flow is perpendicular to the shafts (Fig. 7.6, Layout No. 3). Plants with fewer than four shafts are usually arranged with the flow parallel to the shaft (Fig. 7.6, Layout No. 1).

Rotating biological contactors are covered for several reasons which depend on climatic conditions:

1. Protect biological slime growths from freezing;
2. Prevent intense rains from washing off some of the slime growths;
3. Stop exposure of media to direct sunlight to prevent growth of algae;
4. Avoid exposure of media to sunlight which may cause the media to become brittle; and
5. Provide protection for operators from sun, rain or wind while maintaining equipment.

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[1] *Biodegradable (BUY-o-dee-GRADE-able). Organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odors.*

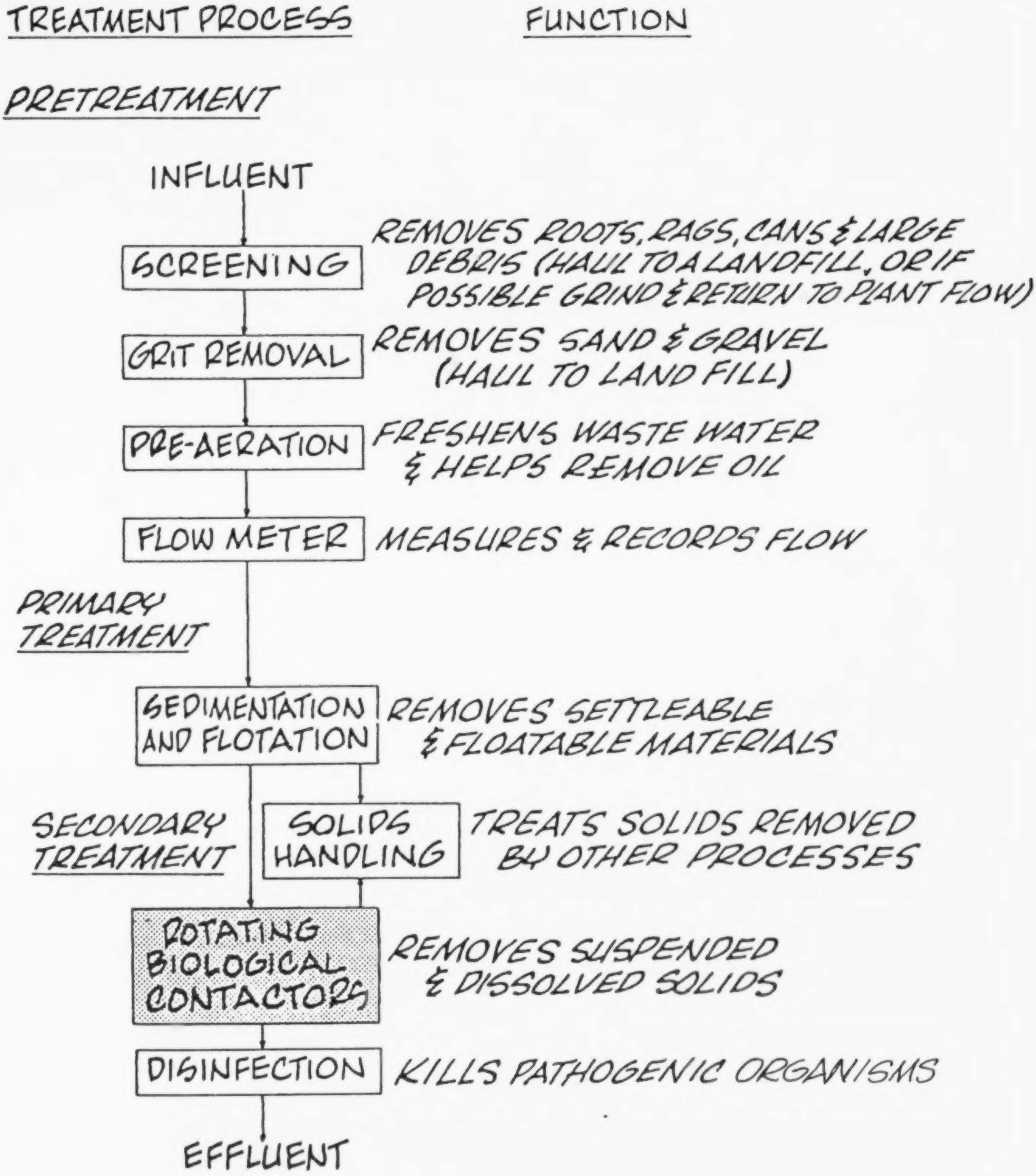

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
ROTATING BIOLOGICAL CONTACTORS
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
EFFLUENT

Fig. 7.1 Flow diagram of treatment plant

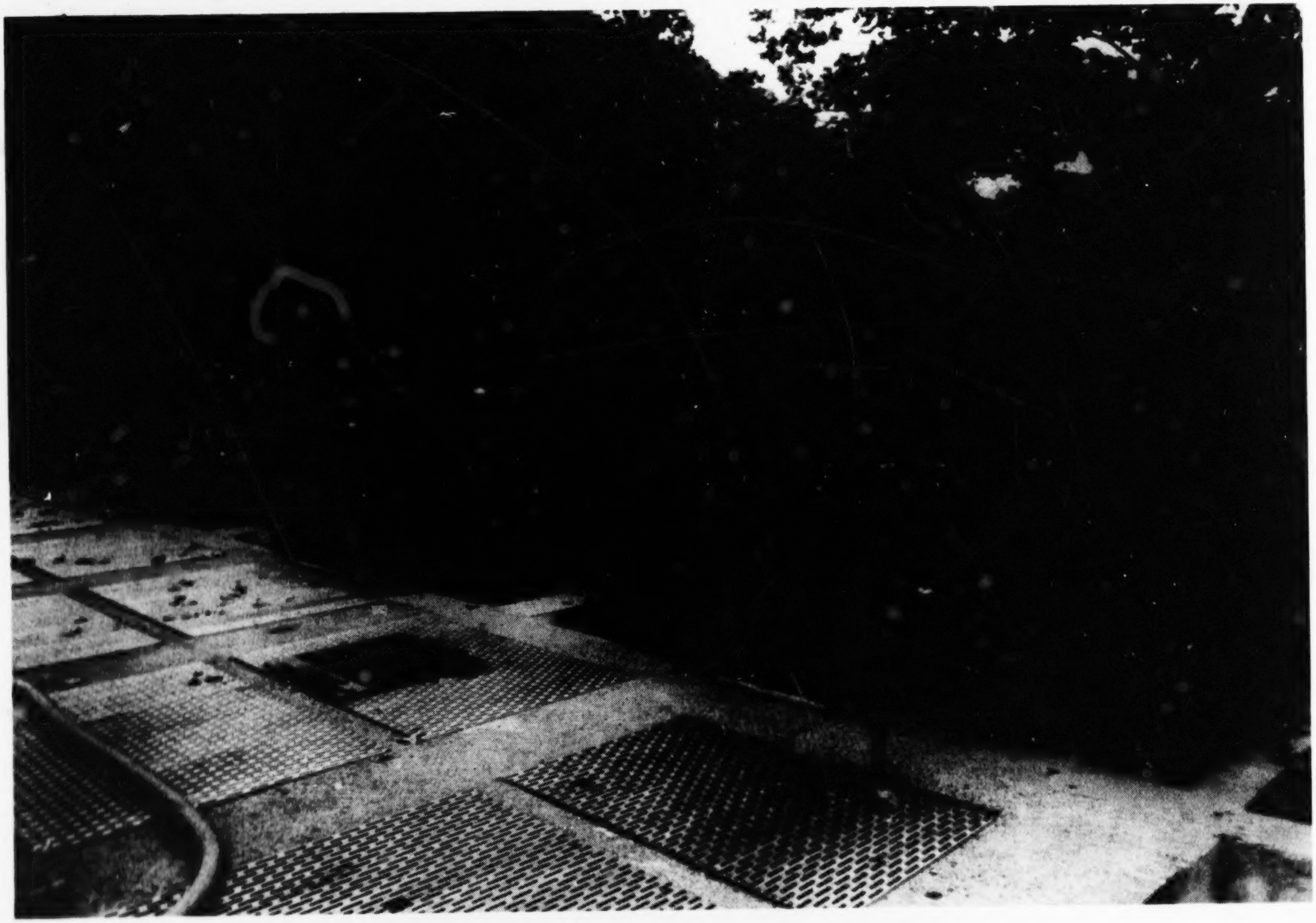


Fig. 7.2 Rotating biological contactors
(Permission of Autotrol Corporation)

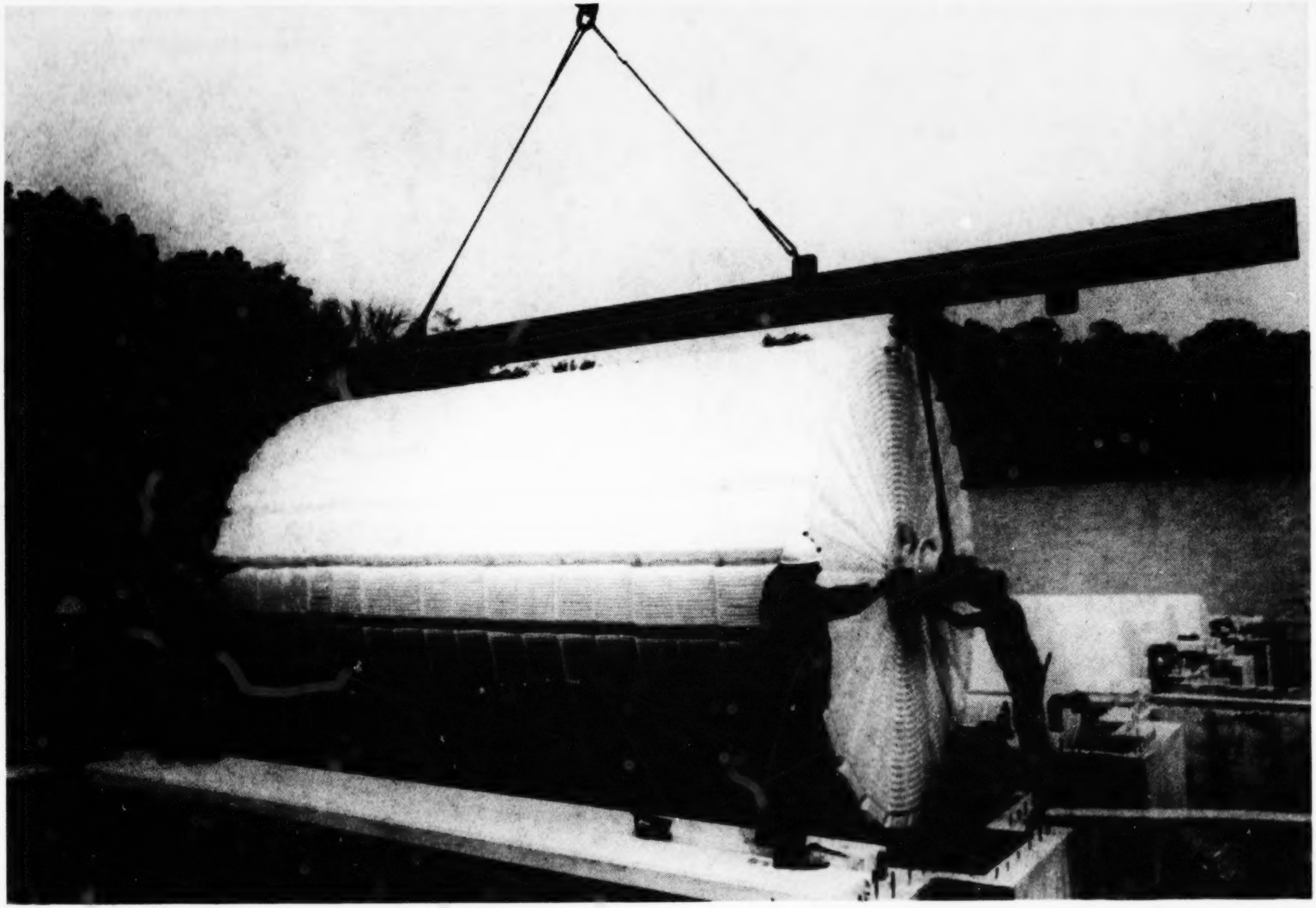
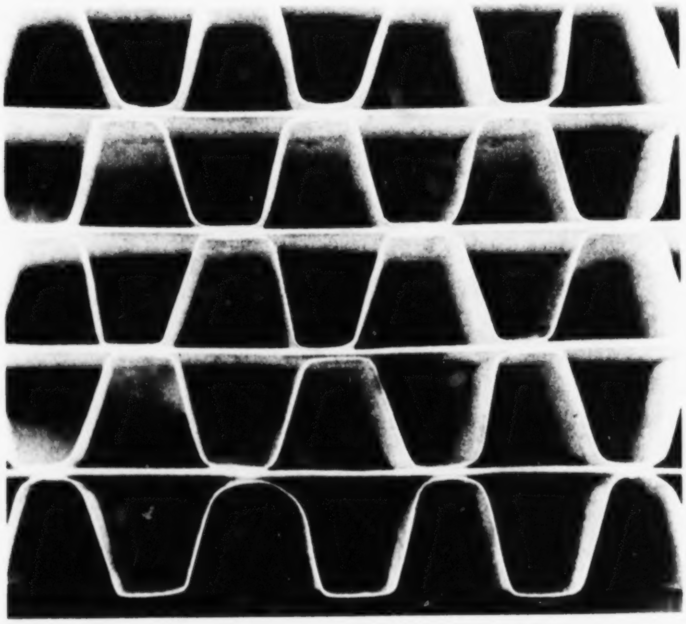
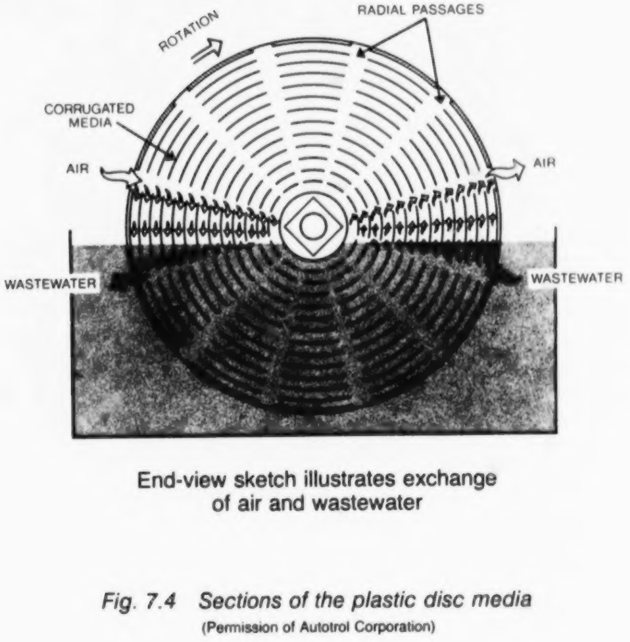


Fig. 7.3 Plastic disc media and biological contactor drum
(Permission of Autotrol Corporation)



Media cross section



ROTATION
RADIAL PASSAGES
CORRUGATED MEDIA
AIR
AIR
WASTEWATER
WASTEWATER

End-view sketch illustrates exchange
of air and wastewater

Fig. 7.4 Sections of the plastic disc media
(Permission of Autotrol Corporation)

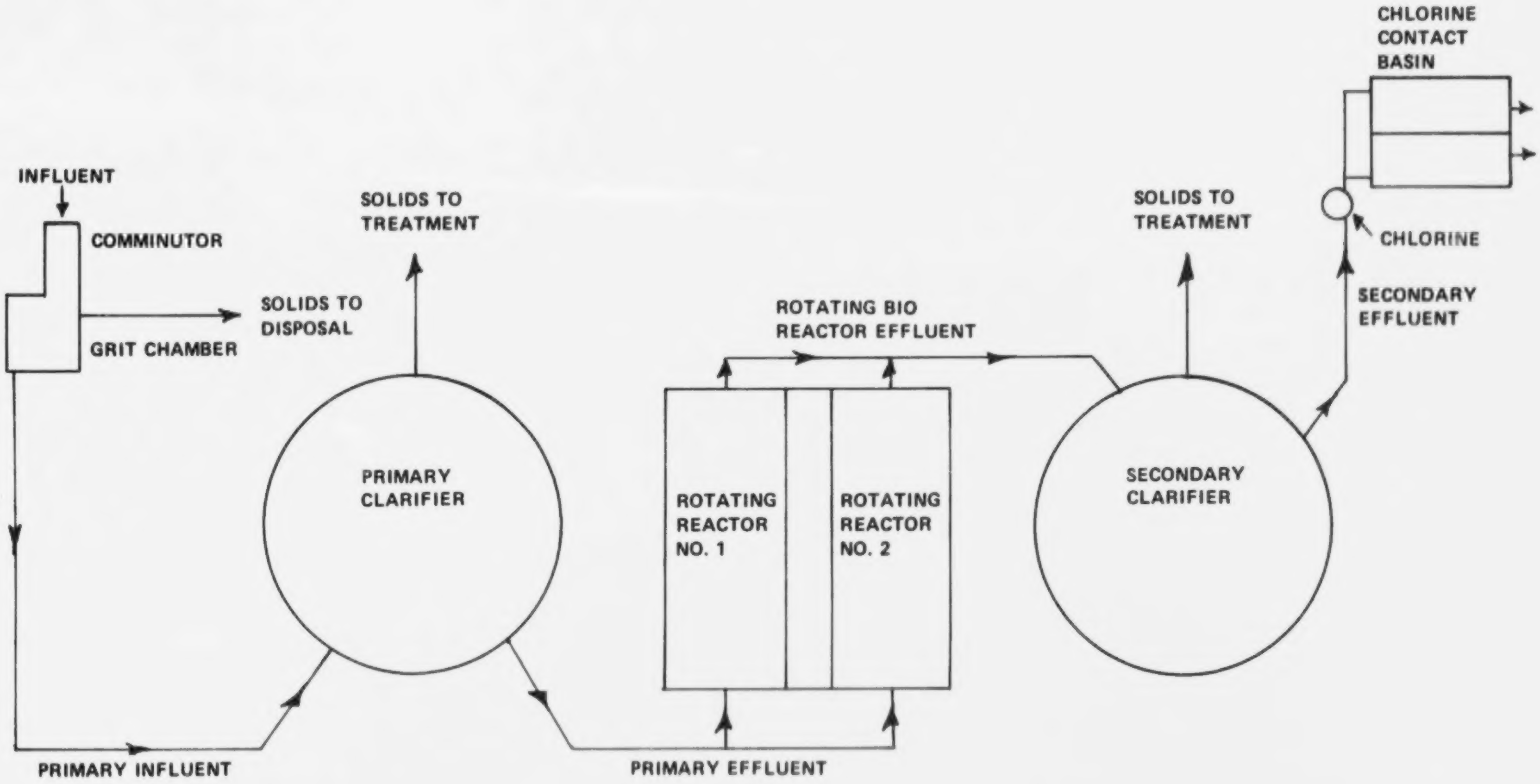
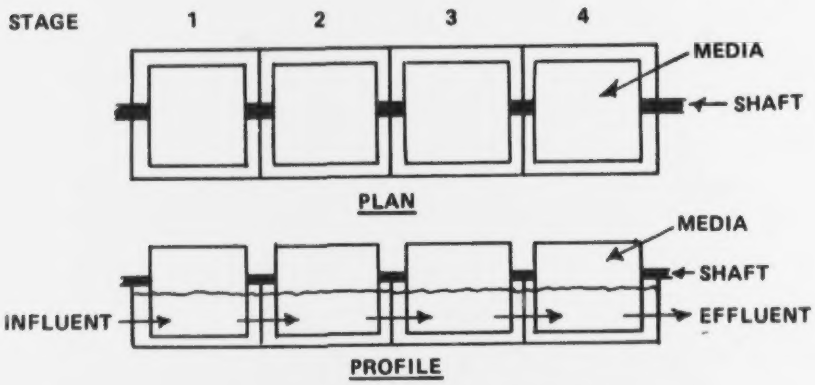

CHLORINE CONTACT BASIN
INFLUENT
COMMINUTOR
SOLIDS TO TREATMENT
SOLIDS TO DISPOSAL
GRIT CHAMBER
ROTATING BIO REACTOR EFFLUENT
SOLIDS TO TREATMENT
CHLORINE
SECONDARY EFFLUENT
PRIMARY CLARIFIER
ROTATING REACTOR NO. 1
ROTATING REACTOR NO. 2
SECONDARY CLARIFIER
PRIMARY INFLUENT
PRIMARY EFFLUENT

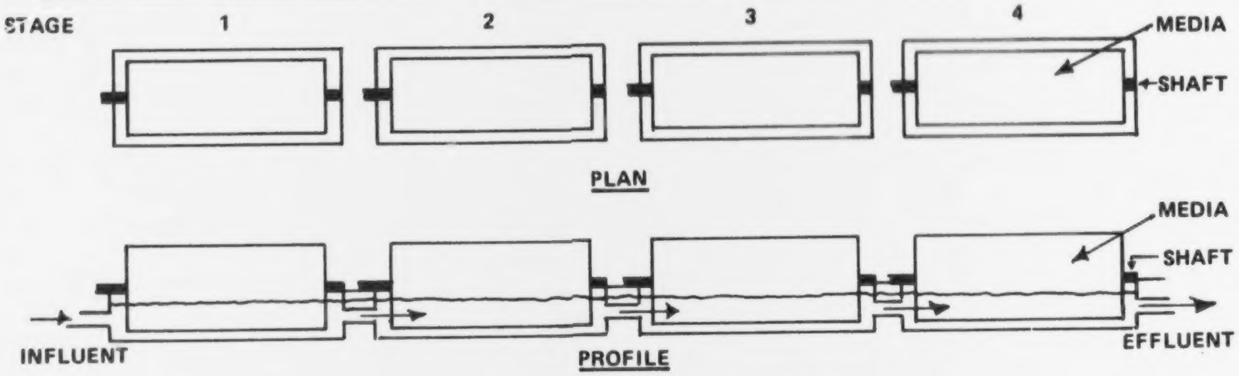
Fig. 7.5 Typical rotating biological contactor (reactor) treatment plant

TABLE 7.1 PURPOSE OF PARTS OF A ROTATING BIOLOGICAL CONTACTOR

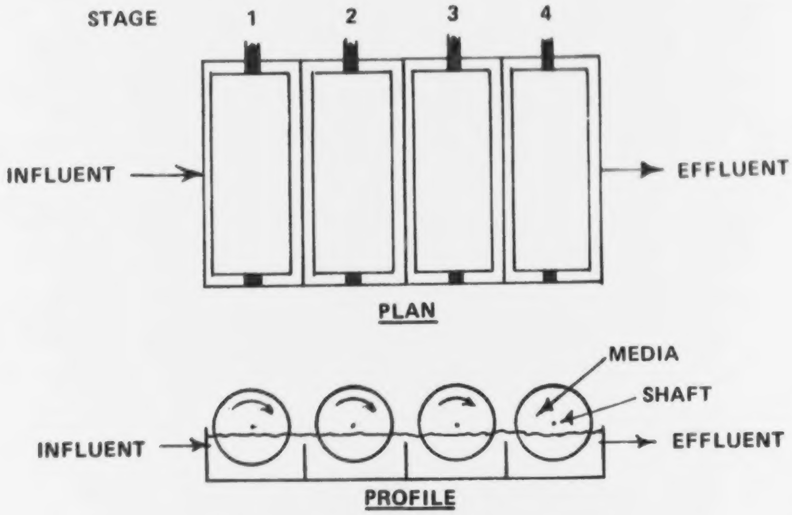
Part	Purpose
1. Concrete or Steel Tank Divided into Bays (Sections) by Baffles (Bulkheads)	Tank. Holds the wastewater being treated and allows the wastewater to come in contact with the organisms on the discs. Bays and baffles. Prevent short-circuiting of wastewater.
2. Orifice or Weir Located in Baffle	Controls flow from one stage to the next stage or from one bay to the next bay.
3. Rotating Media	Provide support for organisms. Rotation provides food (from wastewater being treated) and air for organisms.
4. Cover over Contactor	Protects organisms from severe fluctuations in the weather, especially freezing. Also contains odors.
5. Drive Assembly	Rotates the media.
6. Influent Lines with Valves	Influent lines. Transport wastewater to be treated to the rotating biological contactor. Influent valves. Regulate influent to contactor and also to isolate contactor for maintenance.
7. Effluent Lines with Valves	Effluent lines. Convey treated wastewater from the contactor to the secondary clarifier. Effluent valves. Regulate effluent from the contactor and also isolate contactor for maintenance.
8. Underdrains	Allow for removal of solids which may settle out in tank.


STAGE
1
2
3
4
MEDIA
SHAFT
PLAN
MEDIA
SHAFT
INFLUENT
EFFLUENT
PROFILE

LAYOUT NO. 1 ONE SHAFT, FOUR STAGES
FLOW PARALLEL TO SHAFT


STAGE
1
2
3
4
MEDIA
SHAFT
PLAN
MEDIA
SHAFT
INFLUENT
PROFILE
EFFLUENT

LAYOUT NO. 2 FOUR SHAFTS, FOUR STAGES
FLOW PARALLEL TO SHAFT


STAGE
1
2
3
4
INFLUENT
EFFLUENT
PLAN
MEDIA
SHAFT
INFLUENT
EFFLUENT
PROFILE

LAYOUT NO. 3 FOUR SHAFTS, FOUR STAGES
FLOW PERPENDICULAR TO SHAFT

Fig. 7.6 Possible rotating biological contactor layouts

Fiber glass covers in the shape of the media are easily removed for maintenance. In some areas, the rotating biological contactors are covered by a building. In other areas only a roof is placed over the media for protection against sunlight. The type of cover depends on climatic conditions.

Two types of drive assemblies are used to rotate the shafts supporting the media:

1. Motor with chain drive (Fig. 7.7), and
2. Air drive (Fig. 7.8).

The first type of drive assembly consists of a motor, belt drive, gear or speed reducer, and chain drive. The other drive unit consists of plastic cups attached to the outside of the media (Fig. 7.8). A small air header below the edge of the media releases air into the cups. The air in the cups creates a buoyant force which then makes the shaft turn. With either type of drive assembly, the main shaft is supported by two main bearings.

Individual units are usually provided with influent and effluent line valving to allow isolation for maintenance reasons. Usually the units are not shut down during the low flow conditions because power consumption is minimal and as the flows decrease, the percent of BOD removal increases.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 223.

7.0A How does a rotating biological contactor (RBC) treat wastewater?

7.0B What is the purpose of a cover over the RBC unit?

7.0C Why is the RBC process divided into four stages?

7.0D What are the two types of drive units?

7.1 PROCESS OPERATION

Performance by rotating biological contactors is affected by hydraulic loadings and temperatures below 55°F (13°C). Plants have been designed to treat flows ranging from 18,000 gpd to 50 MGD. Typical operating and performance characteristics are as follows:

Characteristic	**Range**
HYDRAULIC LOADING[2]	
BOD Removal	1.5 to 6 gpd/sq ft
Nitrogen Removal	1.5 to 1.8 gpd/sq ft
ORGANIC LOADING[2] *SOLUBLE BOD*[3]	2.5 to 4 lbs BOD/day/1000 sq ft
BOD Removal	80 to 95 percent
Effluent Total BOD	15 to 30mg/*L*
Effluent Soluble BOD	7 to 15 mg/*L*
Effluent NH_3-N	1 to 10 mg/*L*
Effluent NO_3-N	2 to 7 mg/*L*

See Section 7.5, "Loading Calculations," for procedures showing how to calculate the hydraulic and organic loadings on rotating biological contactors.

Advantages of rotating biological contactors over trickling filters include the elimination of the rotating distributor with its problems, the elimination of the problems cause by ponding on the media, and filter flies. More efficient use of the media is achieved due to the even or uniform rotation of the media into the wastewater being treated. A limitation of the process, as compared with trickling filters, is the lack of flexibility due to the absence of provisions for recirculation; however, in most installations recirculation is not needed.

7.10 Pretreatment Requirements

Rotating biological contactors are usually preceded by pretreatment consisting of screening, grit removal, and primary settling. Grit and large organic matter, if not removed, can settle beneath the drums and form sludge deposits which reduce the effective tank volume, produce septic conditions, scrape the slimes from the media, and possibly stall the unit.

Some rotating biological contactor plants have aerated flow equalization tanks instead of primary clarifiers ahead of the contactors. Flow equalization tanks may be installed to equalize or balance highly fluctuating flows and to allow for the dilution of strong wastes and neutralization of highly acidic or alkaline wastes. These equalization tanks are capable of reducing or eliminating shock loads.

7.11 Start-Up

Prior to plant start-up, become familiar with and understand the contents of the plant O & M manual. If you have any questions, be sure to ask the design engineer or the manufacturer's representative. Both of these persons should instruct the operator on the proper operation of the plant and maintenance of the equipment.

7.110 Pre-Start Checks for New Equipment

Before starting any equipment or allowing any wastewater to enter the treatment process, check the following items:

1. *TIGHTNESS*

   Inspect the following for tightness in accordance with manufacturer's recommendations.

   a. Anchor bolts
   b. Mounting studs
   c. Bearing caps
   Check any torque limitations.
   d. Locking collars
   e. Jacking screws

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[2] *Hydraulic and organic loadings depend on influent flow, influent soluble BOD, effluent BOD, temperature and surface area of plastic media. Manufacturers provide charts converting flow to hydraulic and organic loadings for their media.*

[3] *Soluble BOD. Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.*

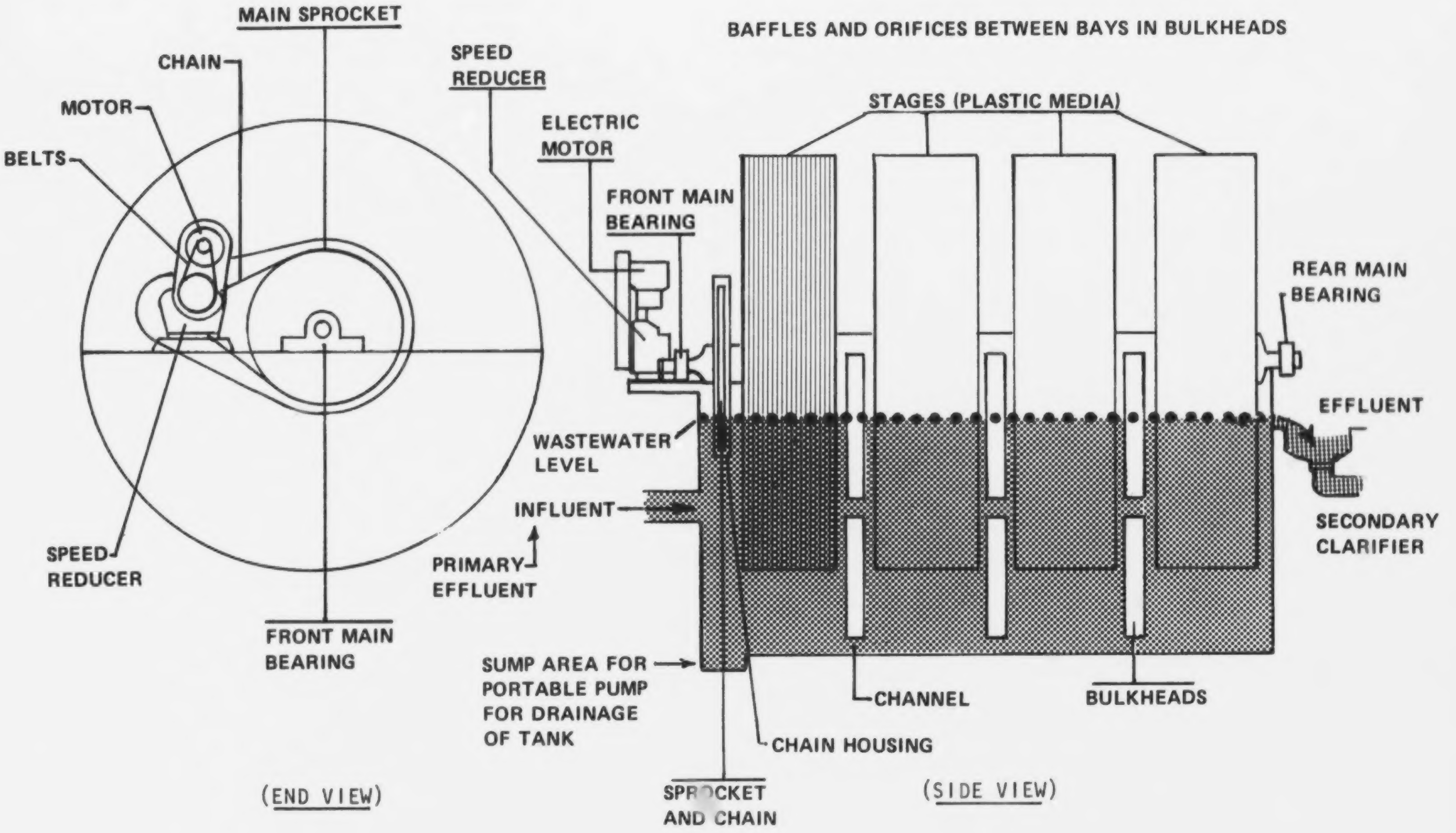
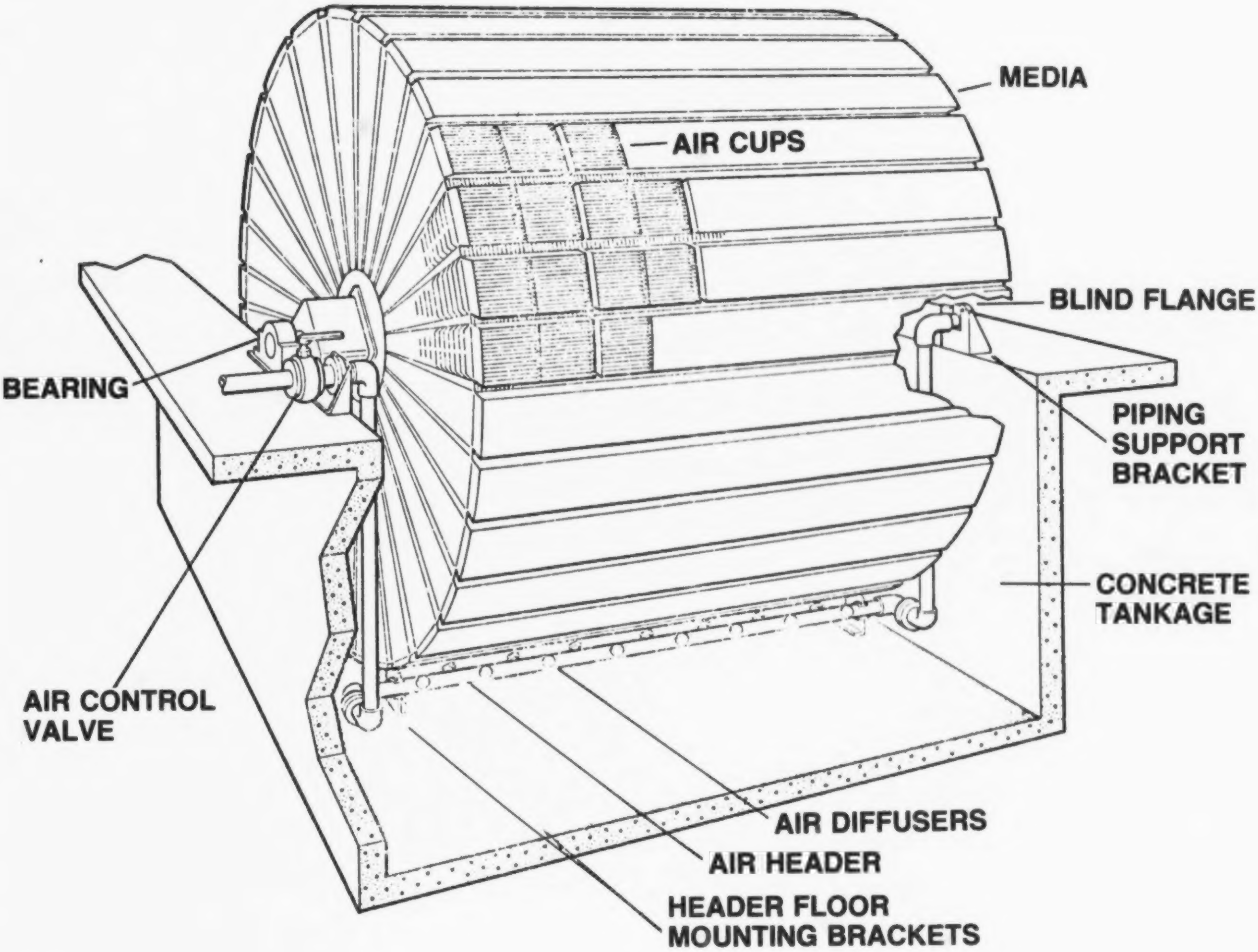

MAIN SPROCKET
CHAIN
MOTOR
BELTS
SPEED REDUCER
FRONT MAIN BEARING
(END VIEW)
SPEED REDUCER
ELECTRIC MOTOR
FRONT MAIN BEARING
BAFFLES AND ORIFICES BETWEEN BAYS IN BULKHEADS
STAGES (PLASTIC MEDIA)
REAR MAIN BEARING
EFFLUENT
SECONDARY CLARIFIER
WASTEWATER LEVEL
INFLUENT
PRIMARY EFFLUENT
SUMP AREA FOR PORTABLE PUMP FOR DRAINAGE OF TANK
CHANNEL
BULKHEADS
CHAIN HOUSING
SPROCKET AND CHAIN
(SIDE VIEW)

Fig. 7.7 Motor with chain drive unit


MEDIA
AIR CUPS
BLIND FLANGE
BEARING
PIPING SUPPORT BRACKET
CONCRETE TANKAGE
AIR CONTROL VALVE
AIR DIFFUSERS
AIR HEADER
HEADER FLOOR MOUNTING BRACKETS

MEDIA
Media with polyethylene air cups attached to the outer perimeter capture air as it is released from the air header.

AIR CUPS
Air cups, attached to the media, capture air which in turn rotates the media.

AIR CONTROL VALVE
Butterfly control valve controls inlet air supply to each unit.

AIR HEADER
Lightweight headers that carry the air through the system run the length of the media assembly and are easily removable for cleaning.

HEADER FLOOR MOUNTING BRACKETS
Brackets secure header to the floor of the tank.

AIR DIFFUSER
Coarse-bubble air diffusers distribute air from the header into the air cups and media.

PIPING SUPPORT BRACKET
Bracket on each end of the header holds unit in place.

Fig. 7.8 Air drive unit
(Permission of Autotrol Corporation)

f. Roller chain
    Be sure chain is properly aligned.
g. Media
    Unbalanced media may cause slippage.
h. Belts
    Use matched sets on multiple-belt drives.

2. *LUBRICATION*

Be sure the following have been properly lubricated with proper lubricants in accordance with manufacturer's recommendations.

a. Mainshaft bearings
b. Roller chain
c. Speed reducer

3. *CLEARANCES*

a. Between media and tank wall.
b. Between media and baffles or cover support beams.
c. Between chain casing and media.
d. Between roller chain, sprockets and chain casing.

4. *SAFETY*

Be sure safety guards are properly installed over chains and other moving parts.

7.111 Procedure for Starting Unit

Actual start-up procedures for a new unit should be in your plant O & M manual and provided by the manufacturer. A typical starting procedure is outlined below.

1. Switch on power, allow shaft to rotate one turn, turn off the power, lock out and tag switch. Inspect and correct if necessary during this revolution:
    a. Movement of chain casing.
    b. Unusual noises.
    c. Direction of media rotation.
        Where wastewater flow is parallel to the rotating media shaft, the direction of rotation is not critical. If the wastewater flow is perpendicular to the rotating media shaft, the media should be moving through the wastewater against the direction of flow (see Figure 7.6, p. 209).
2. Switch on power and allow shaft to rotate for 15 minutes. Inspect the following:
    a. Chain-drive sprocket alignment.
    b. Noises in bearings, chain drives and drive package.
    c. Motor amperage. Compare with nameplate value.
    d. Temperature of mainshaft bearing (by hand) and drive-package pillow block. If too hot for the hand, use a *PYROMETER*[4] or thermometer. Temperature should not exceed 200°F (93°C).
    e. Tightness of shaft bearing-cap bolts. Tighten to manufacturer's recommended torque.
    f. Determine number of revolutions per minute for drum and record for future reference.
3. Open inlet valve and allow wastewater to fill the tank (all four stages if in one tank). Open the outlet valve to allow water to flow through the tank. Turn on power and make inspections listed in steps 1 and 2 again while drum is rotating. Shut off power, lock out and tag switch to make any corrections.
4. Check the relationship between the clarifier inlet and the rotating biological contactor outlet for hydraulic balance. This means that you want to be sure that the tank containing the biological contactor will not overflow and cause stripping of the biomass.
5. See Section 7.20 for break-in maintenance instructions which start after eight hours of operation.

Development of biological slimes can be encouraged by regulating the flow rate and strength of the wastewater applied to nearly constant levels by the use of recirculation if available. Maintaining building temperatures at 65°F (18°C) or higher will help. The best rotating speed is one which will shear off growth at a rate which will provide a constant "hungry and reproductive" film of microorganisms exposed to the wastewater being treated.

Allow one to two weeks for an even growth of biological slimes (biomass) to develop on the surface of the media with normal strength wastewater. After start-up, a slimy growth (biomass) will appear. During the first week, excessive sloughing will occur naturally. This sloughing is normal and the sloughed material is soon replaced with a fairly uniform, shaggy brown-to-gray appearing biomass with very few or no bare spots.

Follow the same start-up procedures whether a plant is starting at less than design flow or at full-design flow. Start-up during cold weather takes longer because the organisms in the slime growth (biomass) are not as active and require more time to grow and reproduce.

7.12 Operation

Rotating biological contactor treatment plants are not difficult to operate and produce a good effluent provided the operator properly and regularly performs the duties of inspecting the equipment, testing the influent and effluent, observing the media, maintaining the equipment and taking corrective action when necessary.

7.120 Inspecting Equipment

This treatment process has relatively few moving parts. There is a drive train to rotate the shaft and there are bearings upon which the shaft rotates. Neither the media nor the shaft require maintenance. Check the following items when inspecting equipment:

1. Feel outer housing of shaft bearing to see if it is running hot. Use a pyrometer or thermometer if temperature is too hot for your hand. If temperature exceeds 200°F (93°C), the bearings may need to be replaced. Also check for proper lubrication and be sure the shaft is properly aligned. The longer the shaft, the more critical the alignment.
2. Listen for unusual noises in motor bearings. Locate cause of unusual noises and correct.
3. Feel motors to determine if they are running hot. If hot, determine cause and correct.
4. Look around drive train and shaft bearing for oil spills. If oil is visible, check oil levels in the speed reducers and chain drive system. Also look for damaged or wornout gaskets or seals.
5. Inspect chain drive for alignment and tightness.
6. Inspect belts for proper tension.
7. Be sure all guards over moving parts and equipment are in place and properly installed.
8. Clean up any spills, messes or debris.

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[4] *Pyrometer (pie-ROM-uh-ter). An apparatus used to measure high temperatures.*

7.121 Testing Influent and Effluent

Wastewater analysis is required to monitor overall plant and process performance. Because there are few process control functions to be performed, only a minimal analysis is required to monitor and report daily performance. To determine if the rotating biological contactors are operating properly, you should measure (1) BOD, (2) suspended solids, (3) pH and (4) dissolved oxygen (DO). Performance is best monitored by analysis of a 24-hour *COMPOSITE SAMPLE*[5] for BOD and suspended solids on a daily basis. DO and pH should be measured using *GRAB SAMPLES*[6] at specific times. Actual frequency of tests may depend on how often you need the results for plant control and also how often your NPDES permit requires you to sample and analyze the plant effluent.

DISSOLVED OXYGEN

The DO in the wastewater being treated beneath the rotating media will vary from stage to stage. A plant designed to treat primary effluent for BOD- and suspended-solids removal will usually have 0.5 to 1.0 mg/*L* DO in the first stage. The DO level will increase to 1 to 3 mg/*L* in the fourth stage. A plant designed for *NITRIFICATION*[7] to convert ammonia and organic nitrogen compounds to nitrate will have four stages also. The difference between a RBC unit designed for BOD removal and one designed for nitrification is the design flow applied per square foot of media surface area. DO in the first stage of nitrification unit will be more than 1 mg/*L* DO and often as high as 2 to 3 mg/*L*. The DO in the fourth stage of a nitrification unit may be as high as 4 to 8 mg/*L*.

EFFLUENT VALUES

Typical BOD, suspended solids, and ammonia and nitrate effluent values for rotating biological contactors depend on NPDES permit requirements and design effluent values. As flows increase, effluent values increase because a greater flow is applied to each square foot of media while the time the wastewater is in contact with the slime growths is reduced. Also, the greater the levels of BOD, suspended solids and nitrogen in the influent, the greater the levels in the plant effluent. Figure 7.9 shows influent and effluent values for a rotating biological contactor. The influent and effluent data plotted are seven-day moving averages which smooth out daily fluctuations and reveal trends. Procedures for calculating moving averages are explained in Chapter 18, "Analysis and Presentation of Data."

If analysis of samples reveals a decrease in process efficiency, look for three possible causes:

1. Reduced wastewater temperatures,
2. Unusual variations in flow and/or organic loadings, and
3. High or low pH values (less than 6.5 or greater than 8.5).

Once the cause of the problem has been identified, possible solutions can be considered and the problem corrected.

TEMPERATURE

Wastewater temperatures below 55°F (13°C) will result in a reduction of biological activity and in a decrease in BOD or organic material removal. Not much can be done by the operator except to wait for the temperatures to increase again. Under severe conditions, provisions can be made to heat the building, the air inside the RBC unit cover, or the RBC unit influent.

Solar heat can be used effectively to maintain temperature in buildings and enclosures without drying out the biological slime growths. Ceilings should be kept low to effectively use available heat. If existing buildings have high ceilings, large vaned fans can be mounted on the ceilings to direct heat downward.

INFLUENT VARIATIONS

When large daily influent flow and/or organic (BOD) variations occur, a reduction in process efficiency is likely to result. Before corrective steps are taken, the exact extent of the problem and resulting change in process efficiency must be determined. In most cases, when the influent flow and/or organic peak loads are less than three times the daily average values during a 24-hour period, little decrease in process efficiency will result.

In treatment plants where the influent flow and/or organic loads exceed design values for a sustained period, the effluent BOD and suspended solids must be measured to determine if corrective action is required.

During periods of severe organic overload, the bulkhead or baffle between stages one and two may be removed. This procedure provides a larger amount of media surface area for the first stage of treatment. If the plant is continuously overloaded and the effluent violates the NPDES permit requirements, additional treatment units should be installed. A possible short-term solution to an overload problem might be the installation of facilities to recycle effluent; however, this would cause a greater increase of any hydraulic overload.

pH

Every wastewater has an optimum pH level for best treatability. Domestic wastewater pH varies between 6.5 and 8.5 and will have little effect on organic removal efficiency. If this range is exceeded at any time (due to industrial waste discharges for example), however, a decrease in efficiency is likely.

To adjust the pH towards 7.0, either pre-aerate the influent or add chemicals. If the pH is too low, add sodium bicarbonate or lime. If the pH is too high, add acetic acid. The amount of chemicals to be added depends on the characteristics of the water and can best be determined by adding chemicals to samples in the lab and measuring the change in pH.

When dealing with nitrification, pH and alkalinity are very critical. The pH should be kept as close as possible to a value of 8.4 when nitrifying. The alkalinity level in the raw wastewater should be maintained at a level at least 7.1 times the influent ammonia concentration to allow the reaction to go to completion without adversely affecting the microorganisms. Sodium bicarbonate can be used to increase both the alkalinity and pH.

Another item under pH variations could be the adding of

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[5] *Composite (Proportional) Sample (com-POZ-it). A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.*

[6] *Grab Sample. A single sample of wastewater taken at neither a set time nor flow.*

[7] *Nitrification (NYE-tri-fi-KAY-shun). A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").*

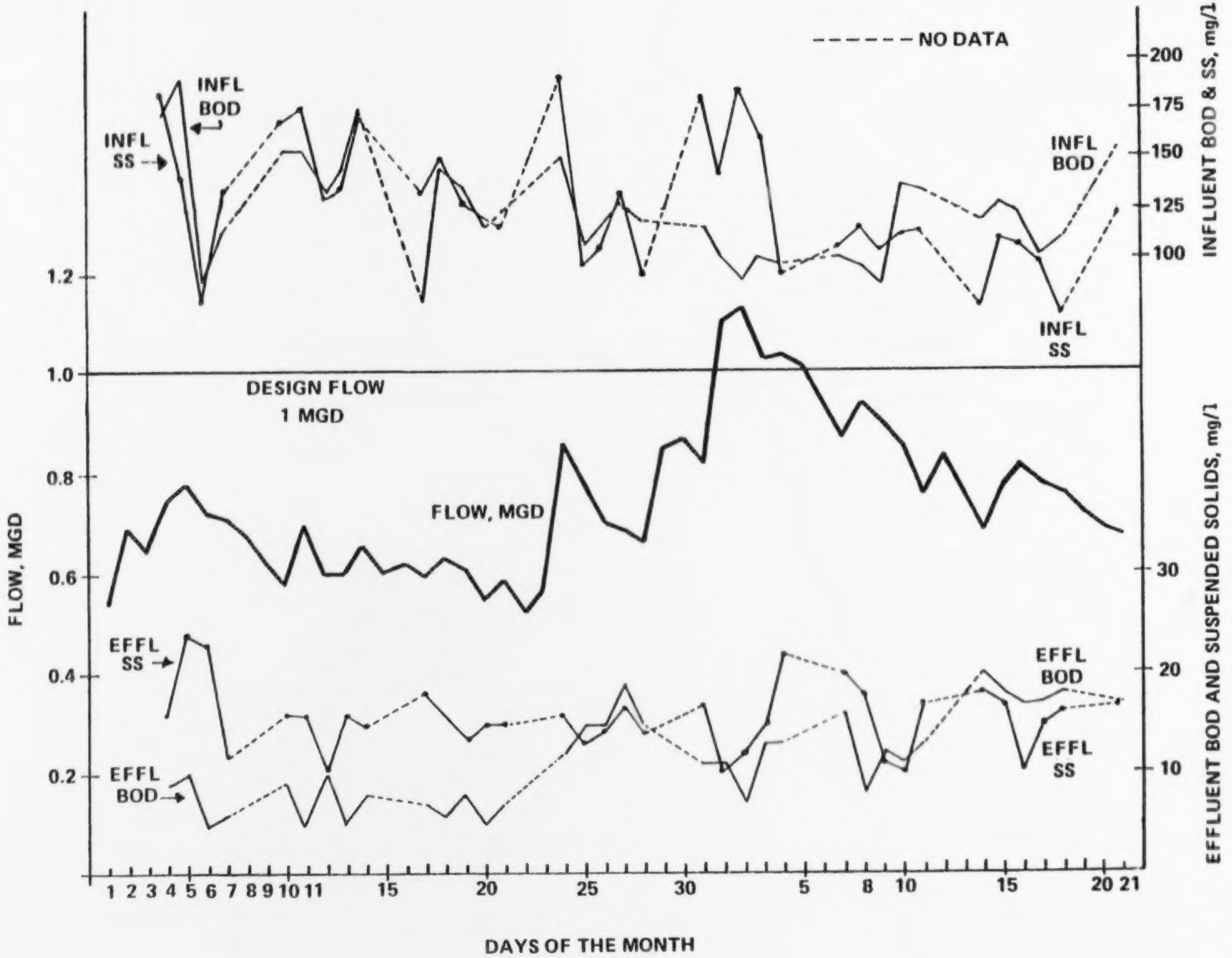


Fig. 7.9 Typical BOD and suspended solids values for an RBC unit

SUPERNATANT[8] from a digester. The supernatant should be tested for pH and suspended solids. Without testing the supernatant, you will not know what kind of load you're placing on the rest of the plant. Sometimes it's best to drain supernatant at low flows to the plant. Caution should be taken to avoid overloading the process. If the supernatant pH is too low, supernatant could be drawn off during high flows when these flows can be used for dilution and *NEUTRALIZATION.*[9]

7.122 Observing the Media

Rotating biological contactors use bacteria and other living organisms growing on the media to treat wastes. Because of this, you can use your sight and smell to identify problems. The slime growth or biomass should have a brown-to-gray color, no algae present, a shaggy appearance with a fairly uniform coverage, and very few or no bare spots. The odor should not be offensive, and certainly there should be no sulfide (rotten egg) smells.

BLACK APPEARANCE

If the appearance becomes black and odors which are not normal do occur, this could be an indication of solids or BOD overloading. These conditions would probably be accompanied by low DO in the plant effluent. Compare previous influent suspended solids and BOD values with current test results to determine if there is an increase. To solve this problem, place another rotating biological contactor unit in service, if possible, or try to pre-aerate the influent to the RBC unit. Also review the operation of the primary clarifiers and sludge digesters to be sure they are not the source of the overload.

WHITE APPEARANCE

A white appearance on the disc surface also might be present during high loading conditions. This might be due to a type of bacteria which feeds on sulfur compounds. The overloading could result from industrial discharges containing sulfur compounds upon which certain sulfur-loving bacteria thrive and produce a white slime biomass. Corrective action consists of placing another RBC unit in service or trying to pre-aerate the influent to the unit. During periods of severe organic or sulfur overloading, remove the bulkhead or baffle between stages one and two. Prechlorination of plant influent also will control sulfur loving bacteria.

Another cause of overloading may be sludge deposits which have been allowed to accumulate in the bottom of the bays. To remove these deposits, drain the bays, wash the sludge deposits out and return unit to service. Be sure the orifices in the baffles between the bays are clear.

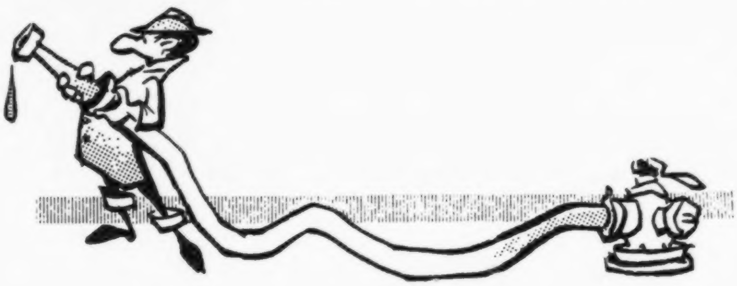
SLOUGHING

If severe sloughing or loss of biomass occurs after the start-up period and process difficulty arises, the causes may be due to the influent wastewater containing toxic or *INHIBITORY SUBSTANCES*[10] that kill the organisms in the biomass or restrict their ability to treat wastes. To solve this problem, steps must be taken to eliminate the toxic substance even though this may be very difficult and costly. Biological processes will never operate properly as long as they attempt to treat toxic wastes. Until the toxic substance can be located and eliminated, loading peaks should be dampened (reduced) and a diluted uniform concentration of the toxic substance allowed to reach the media in order to minimize harm to the biological culture. While the corrections are made at the plant, dampening may be accomplished by regulating inflow to the plant. Be careful not to flood any homes or overflow any low manholes. Toxic wastes may be diluted using plant effluent (until it contains toxic material) or any other source of water supply.

Another problem which could cause loss of biomass is an unusual variation in flow and/or organic loading. In small communities one cause may be high flow during the day and near zero flow at night. During the day the biomass is receiving food and oxygen and starts growing; then the night flow reduces to near zero — available food is reduced and nearly stops. The biomass starts sloughing off again due to lack of food.

Possible solutions to sloughing of the biomass due to excessive variations in plant flow and/or organic loading include throttling peak conditions and recycling from the secondary clarifier or RBC effluent during low flows. Be very careful when throttling plant inflows that low elevation homes are not flooded or that manholes do not overflow. Usually RBC units do not have provisions for any recycling from the secondary clarifier. If low flows at night are creating operation problems due to lack of organic matter, a possible solution is the installation of a pump to recirculate water from the secondary clarifier. If recirculation is provided, try to maintain a hydraulic loading rate of greater than 1.0 to 1.5 gpd/sq ft. A flow equalization tank can be used to provide fairly continuous or even flows.

Possible rotating biological contactor process operational problems, causes and solutions are summarized in Table 7.2.



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[8] *Supernatant (sue-per-NAY-tent). Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.*

[9] *Neutralization (new-trall-i-ZAY-shun). Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.*

[10] *Inhibitory Substances. Materials that kill or restrict the ability of organisms to treat wastes.*

TABLE 7.2 POSSIBLE RBC OPERATIONAL PROBLEMS, CAUSES AND SOLUTIONS

Problem	Cause	Solution
1. Slime on media appears shaggy with a brown-to-gray color.	PROPER OPERATION	NO PROBLEM. NORMAL CONDITION.
2. Black slime	Solids and/or BOD overloading	a. Place another RBC unit in service if available.
		b. Pre-aerate RBC influent.
		c. For severe organic overloads, remove bulkhead or baffle between stages 1 and 2.
3. Rotten egg or other obnoxious odors	Solids and/or BOD overloading	See problem 2, solutions a, b and c above.
4. White slime	Bacteria which feed on sulfur compounds. Also, industrial discharges containing sulfur compounds may cause an overload.	See problem 2, solutions a, b, and c above. Prechlorinate plant influent.
5. Sloughing or loss of slime (biomass)	(1) Toxic or inhibitory substances in influent.	a. Eliminate source of toxic or inhibitory substances.
		b. Reduce peaks of toxic or inhibitory substances by carefully regulating inflow to plant.
		c. Dilute influent using plant effluent or any other source of water.
	(2) Variation in flow and/or organic loading.	a. During low flow or loading periods, pump from secondary clarifier or RBC unit effluent to recycle water with food and DO through the RBC unit.
		b. During high flow or loading conditions, attempt to throttle plant inflow during peak periods.
		c. For severe organic overloads, remove bulkhead or baffle between stages 1 and 2.
6. Decrease in process efficiency	(1) Reduced wastewater temperature.	a. Heat air inside RBC unit cover or building.
		b. Heat influent to unit.
	(2) Unusual variatons in flow and/or organic loading.	See problem 5, cause (2), solutions a, b and c above.
	(3) Sustained flows or loads above design levels.	Install additional treatment units.
	(4) High or low pH values.	a. If the pH is too low, add an alkali (base) such as lime.
		b. If the pH is too high, add an acid such as acetic acid.
	(5) Improper rotation of media.	a. Inspect belt tension and adjust.
		b. Check air pressure and adjust.

7.13 Abnormal Operation

Abnormal operating conditions may develop under the following circumstances:

1. High or low flows,
2. High or low solids loading, and
3. Power outages.

When your plant must treat high or low flows or solids (organic) loads, abnormal conditions develop as the treatment efficiency drops. For solutions to these problems, refer to Section 7.12, "Operation," and Table 7.2. One advantage of RBC units is the fact that high flows usually do not wash the slime growths off the media; consequently the organisms are present and treating the wastewater during and after the high flows.

A power outage requires the operator to take certain precautions to protect the equipment and the slime growths while no power is available. If the power is off for less than four hours, nothing needs to be done. If the power outage lasts longer than four hours, the RBC shaft needs to be turned about one-quarter of a turn every 4 hours. Turning prevents all the slime growth from accumulating on the bottom portion of the plastic disc media. Before attempting to turn the shaft, lock out and tag the power in case the outage ends abruptly. To turn the shaft, *REMOVE THE BELT GUARD USING EXTREME CARE.* Turn the shaft by using the belts. *BE CAREFUL YOU DON'T CUT OFF YOUR FINGERS.* Place a wedge-shaped block between the belts and belt sprocket to hold the shaft and media in the desired location. Actually, the shaft is very delicately balanced and easy to rotate. Do not try to weld handles or brackets to the shaft to facilitate turning because this will throw the shaft off balance.

WARNING. If the shaft starts to roll back to its original position before you get the block properly inserted, do not try to stop the shaft. Let it roll back and stop. If you try to stop the shaft from rolling back, you could injure yourself and also damage the belts and sprockets.

Gently spray water on the slime growth that is not submerged frequently enough to keep the biomass moist whenever the drum is not rotating.

If the power outage lasts longer than 12 hours, more than normal sloughing will occur from the media when the unit is placed back in service. When the sloughing becomes excessive, increase the sludge-pumping rate from the secondary clarifier.

7.14 Shutdown and Restart

The rotating biological contactor may be stopped by turning off the power to the drive package. If the process is to be stopped for longer than four hours, follow the precautions listed in Section 7.13, "Abnormal Operation," when a power outage occurs. Do not allow one portion of the media to be submerged in the wastewater being treated for more than four hours. Occasionally spray the media not submerged to prevent the slime growth from drying out whenever the drum is not rotating.

If the tank holding the wastewater being treated must be drained, a portable sump pump may be used. A sump is usually located at the end of the unit by the motor. Pump the water either to the primary clarifier or to the inlet end of a RBC unit in operation. A trough running the full length of the tank allows the solids to be pumped out. While the tank is empty, inspect for cracks and any other damage and make necessary repairs.

Try to keep the slime growths moist to minimize sloughing and a reduction in organism activity when the process starts again. A loss in process efficiency can result if the slimes are washed off the media. *DO NOT WASH THE SLIME GROWTH OFF THE MEDIA* because you will be washing away the organisms that treat the wastewater. If the unit is to be out of service for longer than one day, the slimes may be washed off the media to prevent the development of odor problems.

Restart rotation by applying power to the drive unit. Before applying power, inspect the shaft and drive unit for possible interference from such items as tools or bulkheads. If slippage occurs from an unbalanced media, inspect and adjust alignment and tension.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 223.

7.1A Why should debris, grit and suspended solids be removed before the wastewater being treated reaches the RBC unit?

7.1B List the major items for a pre-start check.

7.1C What are the main operational duties for an operator of a RBC unit?

7.2 MAINTENANCE

Rotating biological contactors have few moving parts and require minor amounts of preventive maintenance. Chain drives, belt drives, sprockets, rotating shafts and any other moving parts should be inspected and maintained in accordance with manufacturers' instructions or your plant's O & M manual. All exposed parts, bearing housing shaft ends and bolts should be painted or covered with a layer of grease to prevent rust damage. Motors, speed reducers and all other metal parts should be painted for protection.

Maintenance also includes the repair or replacement of broken parts. A preventive maintenance program that keeps equipment properly lubricated and adjusted to help reduce wear and breakage requires less time and money than a program that waits for breakdowns to occur before taking any action. The frequency of inspection and lubrication is usually provided by manufacturer's instructions and also may be found in the plan O & M manual. The following sections indicate a typical maintenance program for a rotating biological contactor treatment process. More detail can be found in a plant O & M manual.

7.20 Break-In Maintenance

AFTER 8 HOURS OF OPERATION

1. Recheck tightening torque of capscrews in all split-tapered bushings in the drive package.
2. Visually inspect hubs and capscrews for general condition and possibility of rubbing against an obstruction.
3. Inspect belt drive (drive package).

AFTER 24 HOURS OF OPERATION

1. Inspect all chain drives.

AFTER 40 HOURS OF OPERATION

1. Inspect all belt drives in drive packages.

AFTER 100 HOURS OF OPERATION

1. Change oil in speed reducer. Use manufacturer's recommended lubricants.

2. Clean magnetic drain plug in speed reducer.
3. Check all capscrews in split-tapered bushings and setscrews in drive package output sprocket and bearing for tightness.
4. Inspect belt drive of drive package.

AFTER 3 WEEKS OF OPERATION

1. Change oil in chain casing. Be sure oil level is at or above the mark on the dipstick. Use manufacturer's recommended lubricants.

7.21 Preventive Maintenance Program

Interval	Procedure
Daily	1. Check for hot shaft and bearings. Replace bearings if temperature exceeds 200°F (93°C).
Daily	2. Listen for unusual noises in shaft and bearing. Identify cause of noise and correct if necessary.
Weekly	3. Grease the mainshaft bearings and drive bearings. Use manufacturer's recommended lubricants. Add grease slowly while shaft rotates. When grease begins to ooze from the housing, the bearings contain the correct amount of grease. Add six full strokes where bearings cannot be seen.
4 wk.	4. Inspect all chain drives.
4 wk.	5. Inspect mainshaft bearings and drive bearings.
4 wk.	6. Apply a generous coating of general purpose grease to mainshaft stub ends, mainshaft bearings and end collars.
3 mo.	7. Change oil in chain casing. Use manufacturer's recommended lubricants. Be sure oil level is at or above the mark on the dipstick.
3 mo.	8. Inspect belt drive.
6 mo.	9. Change oil in speed reducer. Use manufacturer's recommended lubricants.
6 mo.	10. Clean magnetic drain plug in speed reducer.
6 mo.	11. Purge the grease in the double-sealed shaft seals of the speed reducer by removing the plug located 180 degrees from the grease fitting on both the input and output seal cages. Pump grease into the seal cages and then replace the plug. Use manufacturer's recommended grease.
12 mo.	12. Grease motor bearings. Use manufacturer's recommended grease. To grease motor bearings, stop motor and remove drain plugs. Inject new grease with pressure gun until all old grease has been forced out of the bearing through the grease drain. Run motor until all excess grease has been expelled. This may require up to several hours running time for some motors. Replace drain plugs.

7.22 Housekeeping

Properly designed systems have sufficient turbulence so solids or sloughed slime growths should not settle out on the bottom of the bays. If grease balls appear on the water surface in the bays, they should be removed with a dip net or screen device.

If media comes apart, squeeze the two unbonded sections together with a pair of pliers. Take another pair of pliers and force a heated nail through the media. The heat from the nail will melt the plastic and make a plastic weld between the two sections of media.

7.23 Troubleshooting Guide

7.230 Roller Chain Drive

Trouble	Probable Cause	Corrective Action
1. Noisy Drive	1. Moving parts rub stationary parts.	1. Tighten and align casing and chain. Remove dirt or other interfering matter.
	2. Chain does not fit sprockets.	2. Replace with correct parts.
	3. Loose chain.	3. Maintain a taut chain at all times.
	4. Faulty lubrication.	4. Lubricate properly.
	5. Misalignment or improper assembly.	5. Correct alignment and assembly of the drive.
	6. Worn parts.	6. Replace worn chain or bearings. Reverse worn sprockets before replacing.
2. Rapid Wear	1. Faulty lubrication.	1. Lubricate properly.
	2. Loose or misaligned parts.	2. Align and tighten entire drive.
3. Chain Climbs Sprockets	1. Chain does not fit sprockets.	1. Replace chain or sprockets.
	2. Worn-out chain or worn sprockets.	2. Replace chain. Reverse or replace sprockets.
	3. Loose chain.	3. Tighten.
4. Stiff Chain	1. Faulty lubrication.	1. Lubricate properly.
	2. Rust or corrosion.	2. Clean and lubricate.
	3. Misalignment or improper assembly.	3. Correct alignment and assembly of the drive.
	4. Worn-out chain or worn sprockets.	4. Replace chain. Reverse or replace sprockets.
5. Broken Chain or Sprockets	1. Shock or overload.	1. Avoid shock and overload or isolate through couplings.
	2. Wrong size chain, or chain that does not fit sprockets.	2. Replace chain. Reverse or replace sprockets.
	3. Rust or corrosion.	3. Replace parts. Correct corrosive conditions.
	4. Misalignment.	4. Correct alignment.
	5. Interferences.	5. Make sure no solids interfere between chain and sprocket teeth. Loosen chain if necessary for proper clearance over sprocket teeth.

7.231 Belt Drive

Trouble	Probable Cause	Corrective Action
1. Excessive edge wear	1. Misalignment or non-rigid centers.	1. Check alignment and/or reinforcement mounting.
	2. Bent flange.	2. Straighten flange.
2. Jacket wear on pressure-face side of belt tooth.*	Excessive overload and/or excessive belt tightness.	Reduce installation tension and/or increase drive load-carrying capacity.
3. Excessive jacket wear between belt teeth (exposed tension members)*	Excessive installation tension.	Reduce installation tension.
4. Cracks in Neoprene backing	Exposure to excessively low temp. (below −30°F or −35°C).	Eliminate low temperature condition or consult factory for proper belt construction.
5. Softening of Neoprene backing	Exposure to excessive heat (+200°F or 93°C) and/or oil.	Eliminate high temperature and oil condition or consult factory for proper belt construction.
6. Tensile or tooth shear failure.*	1. Small or sub-minimum diameter pulley.	1. Increase pulley diameter.
	2. Belt too narrow.	2. Increase belt width.
7. Excessive pulley tooth wear (on pressure-face and/or OD)*	1. Excessive overload and/or excessive belt tightness.	1. Reduce installation tension and/or increase drive load-carrying capacity.
	2. Insufficient hardness of pulley material.	2. Surface-harden pulley or use harder material.
8. Unmounting of flange	1. Incorrect flange installation.	1. Reinstall flange correctly.
	2. Misalignment.	2. Correct alignment.
9. Excessive drive noise	1. Misalignment.	1. Correct alignment.
	2. Excessive installation tension.	2. Reduce tension.
	3. Sub-minimum pulley diameter.	3. Increase pulley diameters.
10. Tooth shear*	1. Less than 6 teeth in mesh (TIM).	1. Increase TIM or use next smaller pitch.
	2. Excessive load.	2. Increase drive load-carrying capacity.
11. Apparent belt stretch	Reduction of center distance or non-rigid mounting.	Re-tension drive and/or reinforce mounting.
12. Cracks or premature wear at belt tooth root.*	Improper pulley groove top radius.	Regroove or install new pulley.
13. Tensile break	1. Excessive load.	1. Increase load-carrying capacity of drive.
	2. Sub-minimum pulley diameter.	2. Increase pulley diameters.

* Pertains to a timing belt system only.
Recent systems use a V-belt drive.

7.3 SAFETY

Any equipment with moving parts or electrical components should be considered a potential safety hazard. *ALWAYS SHUT OFF THE POWER TO UNIT, TAG THE SWITCH AND LOCK THE POWER SWITCH IN THE "OFF" POSITION BEFORE WORKING ON A UNIT.*

7.30 Slow-Moving Equipment

Slow-moving equipment does not appear dangerous. Unfortunately, moving parts such as the chain sprockets, chain, belt sprockets and belts can cause serious injury by tearing and/or crushing your hands or legs.

7.31 Wiring and Connections

Wiring and connections should be inspected regularly for potential hazards such as loose connections and bare wires. Again, always shut off, tag, and lock out the power switch before working on a unit.

7.32 Slippery Surfaces

Caution must be taken on slippery surfaces. Falls can result in serious injuries. Any spilled oil or grease must be cleaned up immediately. If covers over the media allow sufficient space for walkways, condensed moisture on surfaces will create slippery places. If the temperature of the air within the enclosure can be kept several degrees above the temperature of the wastewater, condensation is significantly reduced. This condensation cannot be avoided completely so walk carefully at all times.

7.33 Infections and Diseases

Precautions must be taken to prevent infections in cuts or open wounds and illnesses from waterborne diseases. After working on a unit, always wash your hands before smoking or eating. *GOOD PERSONAL HYGIENE MUST BE PRACTICED BY ALL OPERATORS AT ALL TIMES.*

7.4 REVIEW OF PLANS AND SPECIFICATIONS

When reviewing plans and specifications, be sure the following items are included in the design of rotating biological contactors.

1. Enclosure to protect biomass from freezing temperature. Enclosure constructed of suitable corrosion-resistant materials and has windows or louvered structures in sides for ventilation. Forced ventilation is not necessary.
2. Heating. A source of heat is helpful during winter operation to minimize the corrosion caused by condensation and to improve operator comfort. If the temperature of the air within the enclosure is kept several degrees above the temperature of the wastewater, condensation is significantly reduced. Ceilings should be kept low to effectively use available heat.
3. Recirculation. Provisions for recirculating secondary effluent and also secondary sludge will allow for flexibility and can improve performance.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 223.

7.2A How often should maintenance be performed on a RBC unit during start-up?

7.3A List some possible safety hazards operators encounter when working around RBC units.

7.5 LOADING CALCULATIONS

7.50 Typical Loading Rates

Hydraulic and organic loadings on rotating biological contactors depend on influent soluble BOD, effluent total and soluble BOD requirements, and wastewater temperature. The loading rates given here are for "typical" values and values for your plant could be different.

Characteristic	Range
Hydraulic Loading	
BOD Removal	1.5 to 6 gpd/sq ft
Nitrogen Removal	1.5 to 1.8 gpd/sq ft
Organic Loading	
Soluble BOD	2.5 to 4 lbs BOD/day/1000 sq ft
Total BOD	6 to 8 lbs BOD/day/1000 sq ft

7.51 Computing Hydraulic Loading

Hydraulic loading on a rotating biological contactor is the amount (gallons) of wastewater per day that flows past the rotating media. To calculate the hydraulic loading, we must know:

1. Gallons per day treated by the rotating contactor, and
2. The surface area of the media in square feet.

EXAMPLE 1

A rotating biological contactor treats a flow of 3.5 MGD. The surface area of the media is 1,000,000 square feet (provided by manufacturer). What is the hydraulic loading in gpd/sq ft?

Known		Unknown
Flow, MGD	= 3.5 MGD	Hydraulic Loading, gpd/sq ft
Surface Area, sq ft	= 1,000,000 sq ft	

1. Calculate the hydraulic loading in gallons per day of wastewater per square foot of surface media.

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gal/day}}{\text{Surface Area, sq ft}}$$

$$= \frac{3{,}500{,}000 \text{ gpd}}{1{,}000{,}000 \text{ sq ft}}$$

$$= 3.5 \text{ gpd/sq ft}$$

7.52 Computing Organic (BOD) Loading

Organic loadings on biological rotating contactors are based on soluble BOD. Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test. If soluble BOD information is not available, soluble BOD may be estimated on the basis of the total BOD and the suspended solids as follows:

$$\text{Soluble BOD, mg}/L = \text{Total BOD, mg}/L - \text{Suspended BOD, mg}/L$$

where

$$\text{Suspended BOD, mg}/L = K \times \text{Suspended Solids, mg}/L$$

Therefore,

$$\text{Soluble BOD, mg}/L = \text{Total BOD, mg}/L - K \times \text{Suspended Solids, mg}/L$$

where

K = 0.5 to 0.7 for most domestic wastewaters.

EXAMPLE 2

The rotating biological contactor in EXAMPLE 1 treats an influent with a total BOD of 200 mg/*L* and suspended solids of 250 mg/*L*. Assume a K value of 0.5 to calculate the soluble BOD. What is the organic loading in pounds of soluble BOD per day per 1000 square feet of media surface?

Known		Unknown
Flow, MGD	= 3.5 MGD	Organic Loading, lbs BOD/day/1000 sq ft
Surface Area, sq ft	= 1,000,000 sq ft	
Total BOD, mg/*L*	= 200 mg/*L*	
SS, mg/*L*	= 250 mg/*L*	
K	= 0.5	

1. Estimate the soluble BOD treated by the rotating biological contactor.

$$\text{Soluble BOD, mg}/L = \text{Total BOD, mg}/L - \left[K \times \text{Suspended Solids mg}/L \right]$$

$$= 200 \text{ mg}/L - (0.5 \times 250 \text{ mg}/L)$$

$$= 200 \text{ mg}/L - 125 \text{ mg}/L$$

$$= 75 \text{ mg}/L$$

2. Determine the soluble BOD applied to the rotating biological contactor in pounds of soluble BOD per day.

$$\text{BOD Applied, lbs/day} = (\text{Soluble BOD, mg}/L)(\text{Flow, MGD})(8.34 \text{ lb/gal})$$

$$= (75 \text{ mg}/L)(3.5 \text{ MGD})(8.34 \text{ lb/gal})$$

$$= 2189 \text{ lbs soluble BOD/day}$$

3. Calculate the organic loading in pounds of soluble BOD per day per 1000 square feet of media surface. Since the media surface area is 1,000,000 square feet, there are 1000 • 1000 square feet of surface area.

$$\text{Organic BOD Loading, lbs BOD/day/1000 sq ft} = \frac{\text{Soluble BOD Applied, lbs BOD/day}}{\text{Surface Area of Media (in 1000 sq ft)}}$$

$$= \frac{2189 \text{ lbs soluble BOD/day}}{1000 \cdot 1000 \text{ sq ft}}$$

$$= 2.2 \text{ lbs BOD/day/1000 sq ft}$$

7.53 Typical Loading Rates (Metric)

The next three sections show typical loading rates for rotating biological contactors and how to calculate the hydraulic and organic loading using the metric system.

Characteristic	Range
Hydraulic Loading	
BOD Removal	0.06 to 0.24 cu m/day/sq m
Nitrogen Removal	0.06 to 0.07 cu m/day/sq m
Organic Loading Soluble BOD	15 to 25 gm/day/sq m

7.54 Computing Hydraulic Loading (Metric)

Hydraulic loading on a rotating biological contactor is the amount (cubic meters) of wastewater per day that flows past the rotating media.

EXAMPLE 3

A rotating biological contactor treats a flow of 15,000 cubic meters per day. The surface area of the media is 100,000 square meters (provided by the manufacturer). What is the hydraulic loading in cu m/day/sq m?

Known		Unknown
Flow, cu m/day	= 15,000 cu m/day	Hydraulic Loading, cu m/day/sq m
Surface Area, sq m	= 100,000 sq m	

1. Calculate the hydraulic loading in cubic meters per day of wastewater per square meter of surface media.

$$\text{Hydraulic Loading, cu m/day/sq m} = \frac{\text{Flow, cu m/day}}{\text{Surface Area, sq m}}$$

$$= \frac{15{,}000 \text{ cu m/day}}{100{,}000 \text{ sq m}}$$

$$= 0.15 \text{ cu m/day/sq m}$$

7.55 Computing Organic (BOD) Loading (Metric)

EXAMPLE 4

The rotating biological contactor in EXAMPLE 3 treats an influent with a soluble BOD of 75 mg/*L*. What is the organic loading in grams of soluble BOD per day per square meter of media surface?

Known		Unknown
Flow, cu m/day	= 15,000 cu m/day	Organic Loading, gm BOD/day/sq m
Surface Areas, sq m	= 100,000 sq m	
Soluble BOD, mg/*L*	= 75 mg/*L*	

1. Determine the soluble BOD applied to the rotating biological contactor in grams of soluble BOD per day.

$$\text{BOD Applied, gm/day} = (\text{BOD, mg}/L)(\text{Flow, cu m/day})(1000 \text{ kg/cu m})(1000 \text{ gm/kg})$$

$$= \frac{75 \text{ mg}}{1{,}000{,}000 \text{ mg}} \times \frac{15{,}000 \text{ cu m}}{\text{day}} \times \frac{1000 \text{ kg}}{\text{cu m}} \times \frac{1000 \text{ gm}}{\text{kg}}$$

$$= 1{,}125{,}000 \text{ gm BOD/day}$$

2. Calculate the organic loading in grams of soluble BOD per day per square meter of media surface.

$$\text{Organic BOD Loading, gm BOD/day/sq m} = \frac{\text{Soluble BOD Applied, gm BOD/day}}{\text{Surface Area of Media, sq m}}$$

$$= \frac{1{,}125{,}000 \text{ gm soluble BOD/day}}{100{,}000 \text{ sq m}}$$

$$= 11.2 \text{ gm BOD/day/sq m}$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 223.

A rotating biological contactor treats a flow of 2.0 MGD with an influent soluble BOD of 100 mg/*L*. The surface area of the media is 500,000 square feet.

7.5A What is the hydraulic loading in gallons per day per square foot?

7.5B What is the organic loading in pounds of soluble BOD per day per 1000 square feet of surface area?

7.6 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read all of Section A.7, Velocity and Flow Rate.

In Section A.13, Typical Wastewater Treatment Plant Problems, read and work the problems in Section A.134, Rotating Biological Contactors.

7.7 ACKNOWLEDGMENT

Mr. Jerry Greene, Autotrol Corporation, reviewed this section and provided helpful suggestions, photographs, drawings and procedures.

7.8 ADDITIONAL READING ON ROTATING BIOLOGICAL CONTACTORS

1. *MOP 11*, Chapter 10,* "Rotating Biological Reactors."
2. *NEW YORK MANUAL*, Chapter 5,* "Secondary Treatment."

*Depends on edition.

7.9 METRIC CALCULATIONS

Refer to Section 7.5, "Loading Calculations," for metric calculations.

END OF
LESSON
ON
ROTATING
BIOLOGICAL
CONTACTORS

DISCUSSION AND REVIEW QUESTIONS

Chapter 7. ROTATING BIOLOGICAL CONTACTORS

Write the answers to these questions in your notebook.

1. Describe the rotating biological contactor (RBC) process and discuss how it works.
2. What RBC equipment would you inspect on a regular basis and how would you do it for a RBC unit?
3. What water quality indicators would you test for in the effluent from a RBC treatment plant?
4. How do the slime growths (biomass) on the plastic media look under (a) normal conditions and (b) abnormal conditions?
5. What factors can cause a decrease in the process efficiency of a RBC unit and how can these problems be corrected?

SUGGESTED ANSWERS

Chapter 7. ROTATING BIOLOGICAL CONTACTORS

Answers to questions on page 208.

7.0A A rotating biological contactor treats wastewater by allowing the slime growths to develop on the surface of plastic media. The slime growths contain organisms that remove the organic materials from the wastewater.

7.0B The purpose of a cover over the RBC unit is to protect organisms from severe changes in weather, especially freezing. Other reasons include preventing heavy rains from washing off slime and protecting operators from weather while maintaining equipment. Also to contain odors and to prevent the growth of algae on the media.

7.0C The RBC process is divided into four stages to increase the effectiveness of a given amount of media surface area. Organisms on the first-stage media are exposed to high levels of BOD and reduce the BOD at a high rate. As the BOD levels decrease from stage to stage, the rate at which the organisms can remove BOD decreases.

7.0D The two types of drive units are:

1. Motor with chain drive, and
2. Air drive.

Answers to questions on page 216.

7.1A Debris, grit and suspended solids should be removed to prevent sludge deposits forming beneath the media. These sludge deposits can reduce the effective tank volume, produce septic conditions, scrape the slimes from the media, and possibly stall the unit.

7.1B The major items on a pre-start check include

1. Tightness of bolts and parts,
2. Lubrication of equipment,
3. Clearances for moving parts, and
4. Insuring that safety guards are properly installed.

7.1C The main operational duties for an operator of an RBC unit include

1. Inspecting equipment,
2. Testing influent and effluent,
3. Observing the media, and
4. Correcting any problems.

Answers to questions on page 220.

7.2A During start-up, maintenance should be performed on an RBC unit:

1. After 8 hours of operation,
2. After 24 hours of operation,
3. After 40 hours of operation,
4. After 100 hours of operation, and
5. After 3 weeks of operation.

7.3A Possible safety hazards to operators working around RBC units include:

1. Moving parts and equipment,
2. Electrical power,
3. Bare electrical wires and loose connections,
4. Slippery surfaces,
5. Infections in cuts and open wounds, and
6. Illnesses from waterborne diseases.

Answers to questions on page 222.

7.5A and 7.5B

Known			**Unknown**
Flow, MGD	= 2.0 MGD	7.5A	Hydraulic Loading, gpd/sq ft
Soluble BOD, mg/*L*	= 100 mg/*L*		
Surface Area, sq ft	= 500,000 sq ft	7.5B	Organic Loading, lbs BOD/day/1000 sq ft

7.5A Calculate the hydraulic loading in gallons per day of wastewater per square foot of surface media.

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gal/day}}{\text{Surface Area, sq ft}}$$

$$= \frac{2{,}000{,}000\text{ gal/day}}{500{,}000\text{ sq ft}}$$

$$= 4\text{ gpd/sq ft}$$

7.5B 1. Determine the soluble BOD applied to the rotating biological contactor in pounds of soluble BOD per day.

$$\text{BOD Applied, lbs/day} = (\text{Soluble BOD, mg/}L)(\text{Flow, MGD})(8.34\text{ lbs/gal})$$

$$= (100\text{ mg/}L)(2.0\text{ MGD})(8.34\text{ lbs/gal})$$

$$= 1668\text{ lbs soluble BOD/day}$$

2. Calculate the organic loading in pounds of soluble BOD per 1000 square feet of media surface.

$$\text{Organic BOD Loading, lbs BOD/day/1000 sq ft} = \frac{\text{Soluble BOD Applied, lbs BOD/day}}{\text{Surface Area of Media (in 1000 sq ft)}}$$

$$= \frac{1668\text{ lbs soluble BOD/day}}{500 \cdot 1000\text{ sq ft}}$$

$$= 3.3\text{ lbs BOD/day/1000 sq ft}$$

END OF ANSWERS TO QUESTIONS IN CHAPTER 7

OBJECTIVE TEST

Chapter 7. ROTATING BIOLOGICAL CONTACTORS

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one answer to each question.

1. Air may be used to rotate the media in a biological contactor.
   1. True
   2. False

2. Coarse-bubble air diffusers may be used to distribute air throughout the tank of a rotating biological contactor.
   1. True
   2. False

3. Solar heat should *NOT* be used to maintain temperature in buildings housing rotating biological contactors because it will dry out the biological slime growths.
   1. True
   2. False

4. When operating a nitrification process, pH and acidity are very critical.
   1. True
   2. False

5. Sodium bicarbonate can be used to decrease both the alkalinity and pH.
   1. True
   2. False

6. The rotating biological contactor treatment process usually contains provisions for recirculation or recycle as does the trickling filter and activated-sludge treatment processes.
   1. True
   2. False

7. Major parts of a rotating biological contactor (RBC) unit include
   1. Aerators.
   2. Drive assembly.
   3. Rotating distributor arms.
   4. Rotating media.
   5. Wearing shoes.

8. Debris, grit and suspended solids should be removed before the wastewater being treated reaches the RBC unit to prevent formation of sludge deposits which can
   1. Increase food to organisms living in slimes.
   2. Produce septic conditions.
   3. Reduce effective tank volume.
   4. Scrape the slimes from the media.
   5. Speed up wastewater treatment.

9. Rotating biological contactors are usually covered to
   1. Increase condensation on biological slime growths.
   2. Prevent growth of algae on media.
   3. Prevent intense rains from washing some of the slime growth off the media.
   4. Prevent winds from blowing slime growths off the media.
   5. Protect biological slime growths from freezing.

10. Factors which could cause a reduction in the wastewater treatment efficiency of an RBC unit include
    1. A toxic substance in the water being treated.
    2. High influent biochemical oxygen demand levels.
    3. High influent flows.
    4. High or low pH values in the influent.
    5. Reduced wastewater temperatures.

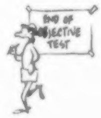
11. What should an operator do when slime growths are sloughing from the plastic media?
    1. If excessive peak inflows have caused the problem, try to throttle inflow during peaks.
    2. If high organic loads have caused sloughing, try removing bulkhead or baffle between stages 1 and 2.
    3. Look for toxic substances which may be killing some of the organisms and control the source.
    4. Turn off the power and allow the media to stop rotating until the slimes can become reattached.
    5. Wash off all the old slimes and allow new slime growths to get started again.

12. An operator must be aware of which of the following safety hazards when working around a RBC treatment unit?
    1. Infections in cuts or open wounds
    2. Loose electrical connections and bare wires
    3. Slippery surfaces caused by water, oil or grease
    4. Slow-moving parts or equipment
    5. Waterborne diseases

13. Flow equalization tanks may be installed ahead of rotating biological contactors to allow for
    1. Balancing of highly fluctuating flows.
    2. Dilution of strong wastes.
    3. Neutralization of highly alkaline wastes.
    4. Precipitation of phosphorus.
    5. Reduction of shock loads.

14. A rotating biological contactor treats a flow of 1.6 MGD. The surface area of the media is 400,000 square feet. What is the hydraulic loading?
    1. 1.0 gpd/sq ft
    2. 2.0 gpd/sq ft
    3. 2.5 gpd/sq ft
    4. 3.0 gpd/sq ft
    5. 4.0 gpd/sq ft

15. A rotating biological contactor treats a flow of 2.2 MGD with an influent soluble BOD of 110 mg/*L*. The surface area of the media is 550,000 square feet. What is the organic loading?
    1. 2.7 lbs BOD/day/1000 sq ft
    2. 3.0 lbs BOD/day/1000 sq ft
    3. 3.5 lbs BOD/day/1000 sq ft
    4. 3.7 lbs BOD/day/1000 sq ft
    5. 4.0 lbs BOD/day/1000 sq ft



CHAPTER 8

ACTIVATED SLUDGE

Volume I. Package Plants and Oxidation Ditches

Volume II, Chapter 11
Operation of Conventional Activated Sludge Plants

ADVANCED WASTE TREATMENT, Chapter 2
Pure Oxygen and Operational Control Alternatives

by

John Brady

Revised by

Ross H. Gudgel

TABLE OF CONTENTS

Chapter 8. Activated Sludge

(Volume I. Package Plants and Oxidation Ditches)

Page

OBJECTIVES 228

GLOSSARY 229

LESSON 1

8.0 The Activated Sludge Process 234
  8.00 Wastewater Treatment by Activated Sludge 234
  8.01 Definitions 234
  8.02 Process Description 234
8.1 Requirements for Control 240

LESSON 2

8.2 Package Plants (Extended Aeration) 241
  8.20 Purpose of Package Plants 241
    8.200 Use of Package Plants 241
    8.201 Types of Package Plant Treatment Processes 241
    8.202 Aeration Methods 245
  8.21 Pre-Start Check-Out 245
  8.22 Starting the Plant 248
  8.23 Operation of Aeration Equipment 248
  8.24 Wasting Sludge 248
  8.25 Operation 248
    8.250 Normal Operation 248
    8.251 Abnormal Operation 249
    8.252 Troubleshooting 249
    8.253 Shutdown 249
    8.254 Operational Strategy 249
  8.26 Laboratory Testing 250
  8.27 Safety 250
  8.28 Maintenance 251
  8.29 Additional Reading 251

LESSON 3

8.3 Oxidation Ditches 252
  8.30 Use of Oxidation Ditches 252
    8.300 Flow Path for Oxidation Ditches 252
    8.301 Description of Oxidation Ditches 252
  8.31 Safety 255
  8.32 Start-Up 255
    8.320 Pre-Start Inspection 255
    8.321 Plant Start-Up 256
  8.33 Operation 257
    8.330 Normal Operation 257
    8.331 Abnormal Operation 260
    8.332 Shutdown 260
    8.333 Troubleshooting 260
    8.334 Operational Strategy 262
  8.34 Maintenance 262
    8.340 Housekeeping 262
    8.341 Equipment Maintenance 262
  8.35 Operational Guidelines 263
    8.350 English System 263
    8.351 Metric System 264
8.4 Review of Plans and Specifications 265
  8.40 Package Plants 265
  8.41 Oxidation Ditches 265
8.5 Arithmetic Assignment 266
8.6 Metric Calculations 266

OBJECTIVES

Chapter 8. ACTIVATED SLUDGE

The activated sludge process is a very important wastewater treatment process. For this reason, the chapters on activated sludge have been divided into three parts and will be presented in three separate manuals.

I. Package Plants and Oxidation Ditches (Volume I)
II. Conventional Activated Sludge Plants (Volume II)
III. Pure Oxygen Plants and Operational Control (*ADVANCED WASTE TREATMENT*)

If you are the operator of a package plant or oxidation ditch, Volume I will provide you with the information you need to know to operate your plant. Volume II and *ADVANCED WASTE TREATMENT* will help you better understand the activated sludge plant or a modification. Volume I will help you understand the activated sludge process and Volume II will tell you how to operate your plant. *ADVANCED WASTE TREATMENT* will explain to you alternative means of operational control that may work very well for your plant. If you operate a pure oxygen plant, *ADVANCED WASTE TREATMENT* will tell you what you need to know to operate the pure oxygen system. All three parts contain information important to the proper operation of your plant. *ADVANCED WASTE TREATMENT* also contains information helpful to operators using the activated sludge process to treat special wastes such as industrial wastes.

appropriate part on activated sludge you should be able to do the following:

1. Explain the principles of the activated sludge process and the factors that influence and control the process,
2. Inspect a new activated sludge facility for proper installation,
3. Place a new activated sludge process into service,
4. Schedule and conduct operation and maintenance duties,
5. Collect samples, interpret lab results, and make appropriate adjustments in treatment processes,
6. Recognize factors that indicate an activated sludge process is not performing properly, identify the source of the problem, and take corrective action.
7. Conduct your duties in a safe fashion,
8. Determine aerator loadings and understand the application of different loading guidelines,
9. Keep records for an activated sludge plant,
10. Identify the common modifications of the activated sludge process, and
11. Review plans and specifications for an activated sludge plant.

GLOSSARY

Chapter 8. ACTIVATED SLUDGE

ABSORPTION (ab-SORP-shun) ABSORPTION

Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACTIVATED SLUDGE (ACK-ta-VATE-ed sluj) ACTIVATED SLUDGE

Sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, fungi, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.

ACTIVATED SLUDGE PROCESS ACTIVATED SLUDGE PROCESS
(ACK-ta-VATE-ed sluj)

A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.

ADSORPTION (add-SORP-shun) ADSORPTION

The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.

AERATION LIQUOR (air-A-shun) AERATION LIQUOR

Mixed liquor. The contents of the aeration tank including living organisms and material carried into the tank by either untreated wastewater or primary effluent.

AERATION TANK (air-A-shun) AERATION TANK

The tank where raw or settled wastewater is mixed with return sludge and aerated. The same as aeration bay, aerator or reactor.

AEROBES AEROBES

Bacteria that must have molecular (dissolved) oxygen (DO) to survive.

AEROBIC DIGESTION (AIR-O-bick) AEROBIC DIGESTION

The breaking down of wastes by microorganisms in the presence of dissolved oxygen. Waste sludge is placed in a large aerated tank where aerobic microorganisms decompose the organic matter in the sludge. This is an extension of the activated sludge process.

AGGLOMERATION (a-GLOM-er-A-shun) AGGLOMERATION

The growing or coming together of small scattered particles into larger flocs or particles which settle rapidly. Also see FLOC.

AIR-LIFT AIR-LIFT

A special type of pump. This device consists of a vertical riser pipe submerged in the wastewater or sludge to be pumped. Compressed air is injected into a tail piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An air-lift pump works similar to the center stand in a percolator coffee pot.

ALIQUOT (AL-li-kwot) ALIQUOT

Portion of a sample.

ANAEROBES ANAEROBES

Bacteria that do not need molecular (dissolved) oxygen (DO) to survive.

BACTERIAL CULTURE (back-TEAR-e-al) BACTERIAL CULTURE

In the case of activated sludge, the bacterial culture refers to the group of bacteria classed as *AEROBES* and facultative organisms, which covers a wide range of organisms. Most treatment processes in the United States grow facultative organisms which utilize the carbonaceous (carbon compounds) BOD. Facultative organisms can live when oxygen resources are low. When "nitrification" is required, the nitrifying organisms are *OBLIGATE AEROBES* (require oxygen) and must have at least 0.5 mg/*L* of dissolved oxygen throughout the whole system to function properly.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

BIOMASS (BUY-o-MASS) BIOMASS

A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris. This mass may be formed for, or function as, the protection against predators and storage of food suplies. Also see ZOOGLEAL MASS.

BULKING (BULK-ing) BULKING

Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.

COAGULATION (ko-AGG-u-LAY-shun) COAGULATION

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COMPOSITE (PROPORTIONAL) SAMPLE (com-POZ-it) COMPOSITE (PROPORTIONAL) SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

CONING (CONE-ing) CONING

Development of a cone-shaped flow of liquid, like a whirlpool, through sludge. This can occur in a sludge hopper during sludge withdrawal when the sludge becomes too thick. Part of the sludge remains in place while liquid rather than sludge flows out of the hopper. Also called "coring."

CONTACT STABILIZATION CONTACT STABILIZATION

Contact stabilization is a modification of the conventional activated sludge process. In contact stabilization, two aeration tanks are used. One tank is for separate re-aeration of the return sludge for at least four hours before it is permitted to flow into the other aeration tank to be mixed with the primary effluent requiring treatment.

DENITRIFICATION DENITRIFICATION

A condition that occurs when nitrate or nitrite ions are reduced to nitrogen gas and bubbles are formed as a result of this process. The bubbles attach to the biological flocs and float the flocs to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers.

DIFFUSED-AIR AERATION DIFFUSED-AIR AERATION

A diffused air activated sludge plant takes air, compresses it, and then discharges the air below the water surface of the aerator through some type of air diffusion device.

DIFFUSER DIFFUSER

A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DISSOLVED OXYGEN DISSOLVED OXYGEN

Molecular oxygen dissolved in water or wastewater, usually abbreviated DO.

ENDOGENOUS (en-DODGE-en-us) ENDOGENOUS

A reduced level of respiration (breathing) in which organisms break down compounds within their own cells to produce the oxygen they need.

F/M RATIO F/M RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\ \text{lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\ \text{lbs/gal}}$$

$$\text{or} = \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

FACULTATIVE (FACK-ul-tay-tive) FACULTATIVE

Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, facultative bacteria can live under aerobic or anaerobic conditions.

FILAMENTOUS BACTERIA (FILL-a-MEN-tuss) FILAMENTOUS BACTERIA

Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.

FLIGHTS FLIGHTS

Scraper boards, made from redwood or other rot-resistant woods or plastic, used to collect and move settled sludge or floating scum.

FLOC FLOC

Groups or clumps of bacteria and particles that have come together and formed a cluster. Found in aeration tanks and secondary clarifiers.

FOOD/MICROORGANISM RATIO FOOD/MICROORGANISM RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\ \text{lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\ \text{lbs/gal}}$$

$$\text{or} = \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

Commonly abbreviated F/M Ratio.

HEADER HEADER

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "manifold."

MANIFOLD MANIFOLD

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "header."

MEAN CELL RESIDENCE TIME (MCRT) MEAN CELL RESIDENCE TIME (MCRT)

An expression of the average time that a microorganism will spend in the activated sludge process.

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lbs/day}}$$

MECHANICAL AERATION MECHANICAL AERATION

The use of machinery to mix air and water so that oxygen can be absorbed into the water. Some examples are: paddle wheels, mixers, or rotating brushes to agitate the surface of an aeration tank; pumps to create fountains; and pumps to discharge water down a series of steps forming falls or cascades.

MICROORGANISMS (micro-ORGAN-is-ums) MICROORGANISMS

Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

MIXED LIQUOR MIXED LIQUOR

When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank. When the mixed liquor flows from the aeration tank it goes into the secondary clarifiers or final sedimentation tanks. Mixed liquor also may refer to the contents of mixed aerobic or anaerobic digesters.

MIXED LIQUOR SUSPENDED SOLIDS
(MLSS)

MIXED LIQUOR SUSPENDED SOLIDS
(MLSS)

Suspended solids in the mixed liquor of an aeration tank.

MIXED LIQUOR VOLATILE SUSPENDED
SOLIDS (MLVSS)

MIXED LIQUOR VOLATILE SUSPENDED
SOLIDS (MLVSS)

The organic or volatile suspended solids in the mixed liquor of an aeration tank.

NITRIFICATION (NYE-tri-fi-KAY-shun)

NITRIFICATION

A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

OXIDATION (ox-i-DAY-shun)

OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances. The opposite of REDUCTION.

POLYELECTROLYTE (POLY-electro-light)

POLYELECTROLYTE

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polymer."

POLYMER (POLY-mer)

POLYMER

A chemical formed by the union of many monomers (a molecule of low molecular weight). Polymers are used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. All polyelectrolytes are polymers, but not all polymers are polyelectrolytes.

PROTOZOA (pro-toe-ZOE-ah)

PROTOZOA

A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.

REDUCTION (re-DUCK-shun)

REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions in wastewater, sulfate compounds or elemental sulfur are reduced to odor-producing hydrogen sulfide (H_2S) or the sulfide ion (S^{-2}). The opposite of OXIDATION.

RISING SLUDGE

RISING SLUDGE

Rising sludge occurs in the secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.

SECCHI DISC (SECK-key)

SECCHI DISC

A flat, white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded secchi disc reading.

SEIZING

SEIZING

Seizing occurs when an engine overheats and a component expands so the engine will not run. Also called "freezing."

SEPTIC (SEP-tick)

SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SHOCK LOAD

SHOCK LOAD

The arrival at a plant of a waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and solids in the effluent. Organic or hydraulic overloads can cause a shock load.

SLUDGE AGE

SLUDGE AGE

A measure of the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process.

$$\text{Sludge Age, days} = \frac{\text{Suspended Solids Under Aeration, lbs or kg}}{\text{Suspended Solids Added, lbs/day or kg/day}}$$

SLUDGE DENSITY INDEX (SDI)

SLUDGE DENSITY INDEX (SDI)

This test is used in a way similar to the Sludge Volume Index (SVI) to indicate the settleability of a sludge in a secondary clarifier or effluent. SDI = 100/SVI. Also see SLUDGE VOLUME INDEX (SVI).

SLUDGE VOLUME INDEX (SVI) SLUDGE VOLUME INDEX (SVI)

This is a test used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared to its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light or lighter than water.

$$\text{SVI} = \frac{\text{Wet Settled Sludge, ml}}{\text{Dried Sludge Solids, mg}} \times 1000$$

STABILIZED WASTE STABILIZED WASTE

A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

STEP-FEED AERATION STEP-FEED AERATION

Step-feed aeration is a modification of the conventional activated sludge process. In step aeration, primary effluent enters the aeration tank at several points along the length of the tank, rather than all of the primary effluent entering at the beginning or head of the tank and flowing through the entire tank.

SUPERNATANT (sue-per-NAY-tent) SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.

TOC TOC

Total Organic Carbon. TOC measures the amount of organic carbon in water.

TURBIDITY METER TURBIDITY METER

An instrument for measuring the amount of particles suspended in water. Precise measurements are made by measuring how light is scattered by the suspended particles. The normal measuring range is 0 to 100 and is expressed as Nephelometric Turbidity Units (NTU's).

VOLUTE (vol-LOOT) VOLUTE

The spiral-shaped casing which surrounds a pump, blower, or turbine impeller and collects the liquid or gas discharged by the impeller.

ZOOGLEAL MASS (ZOE-glee-al) ZOOGLEAL MASS

Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes. These masses may be formed for or function as the protection against predators and for storage of food supplies. Also see BIOMASS.

(VER-e PRIT-ee)

CHAPTER 8. ACTIVATED SLUDGE

(Lesson 1 of 3 Lessons)

8.0 THE ACTIVATED SLUDGE PROCESS

8.00 Wastewater Treatment by Activated Sludge

When wastewater enters an activated sludge plant, the pretreatment processes (Chapter 4) remove the coarse or heavy solids (grit) and other debris, such as roots, rags, and boards. Primary clarifiers (Chapter 5) remove much of the floatable and settleable material. Normally settled wastewater is treated by the activated sludge process, but in some plants the raw wastewater flows from the pretreatment processes directly to the activated sludge process.

8.01 Definitions

ACTIVATED SLUDGE (Fig. 8.1). Activated sludge consists of sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, fungi, and protozoa.

ACTIVATED SLUDGE PROCESS (Fig. 8.2). The activated sludge process is a biological wastewater treatment process that uses *MICROORGANISMS*[1] to speed up decomposition of wastes. When activated sludge is added to wastewater, the microorganisms feed and grow on waste particles in the wastewater. As the organisms grow and reproduce, more and more waste is removed, leaving the wastewater partially cleaned. To function efficiently, the mass of organisms (*SOLIDS CONCENTRATION*[2]) needs a steady balance of food (*FOOD/MICROORGANISM RATIO*[3]) and oxygen.

8.02 Process Description

Secondary treatment in the form of the activated sludge process (Figs. 8.3 and 8.4) is aimed at *OXIDATION*[4] and removal of soluble or finely divided suspended materials that were not removed by previous treatment. Aerobic organisms do this in a few hours as wastewater flows through an aeration tank. The organisms *STABILIZE*[5] soluble or finely divided suspended solids by partial oxidation forming carbon dioxide, water, and sulfate and nitrate compounds. The remaining solids are changed to a form that can be settled and removed as sludge during sedimentation.

AERATION TANK
SETTLED ORGANISMS

After the aeration period, the wastewater is routed to a secondary settling tank for a liquid-organism (water-solids) separation. Settled organisms are quickly returned to the aeration tank as activated sludge. The remaining clarifier effluent is usually chlorinated and discharged from the plant.

Conversion of dissolved and suspended material to settleable solids is the main objective of high-rate activated sludge processes, while low-rate processes stress oxidation. The oxidation may be by chemical or biological processes. In the activated sludge process, the biochemical oxidation carried out by living organisms is stressed. The same organisms also are effective in conversion of substances to setteable solids if the plant is operated properly.

When wastewater enters the aeration tanks, it is mixed with the activated sludge to form a mixture of sludge, carrier water, and influent solids. These solids come from roofs or streets in combined sewer systems and also from the discharges from homes, factories, and businesses. The activated sludge which is added contains many different types of helpful living organisms that were grown during previous contact with wastewater. These organisms are the workers in the treatment process. They use the incoming wastes for food and as a source of energy for their life processes and for the reproduction of more organisms. These organisms will use more food contained in the wastewater in treating the wastes. The activated sludge also forms a lacy network or floc mass that entraps many materials not used as food.

Some organisms (workers) will require a long time to use the available food in the wastewater at a given waste concentration. Many organisms will compete with each other in the use of available food (waste) to shorten the time factor and increase the portion of waste stabilized. The ratio of food to organisms is a primary control in the activated sludge process.

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[1] *Microorganisms (micro-ORGAN-is-ums). Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.*

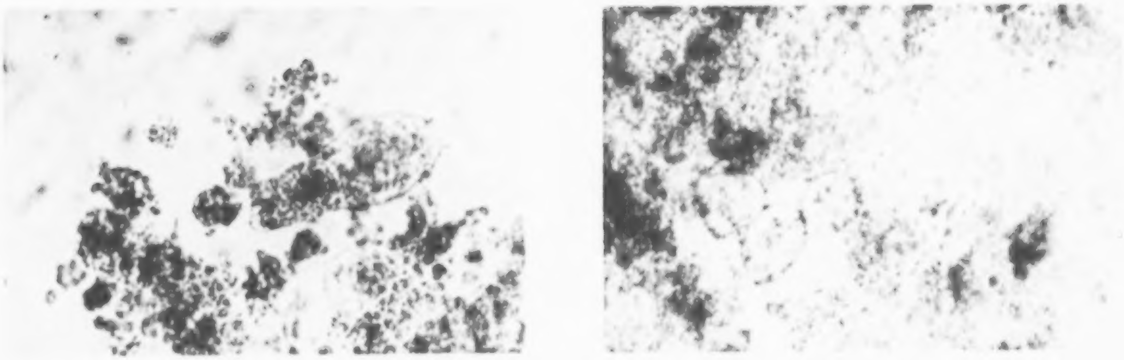
[2] *Solids Concentration. The solids in the aeration tank carry microorganisms that feed on wastewater.*

[3] *Food/Microorganism Ratio. Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.*

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day or kg/day}}{\text{MLVSS, lbs or kg}}$$

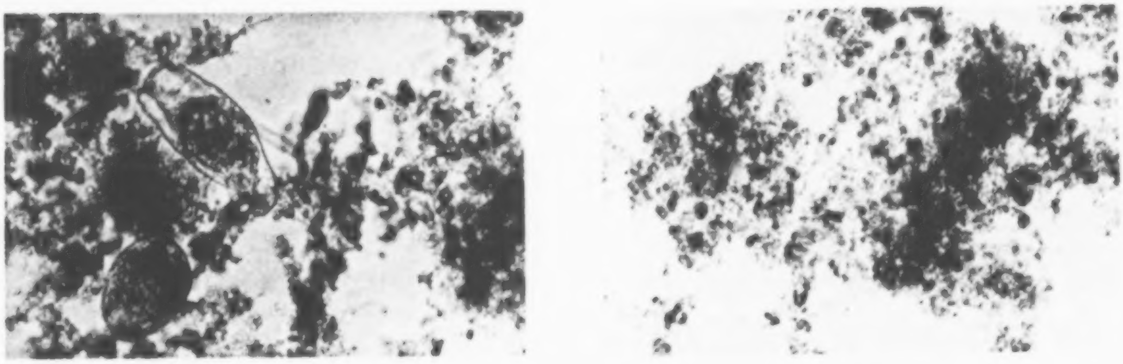
[4] *Oxidation (ox-i-DAY-shun). Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances.*

[5] *Stabilized Waste. A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.*



Rotifer

Opercularia



Rotifer and opercularia

Zoogleal mass

Fig. 8.1 Microorganisms in activated sludge

For information on the use of microorganisms to operate the activated sludge process, see Chapter 21, "Activated Sludge."

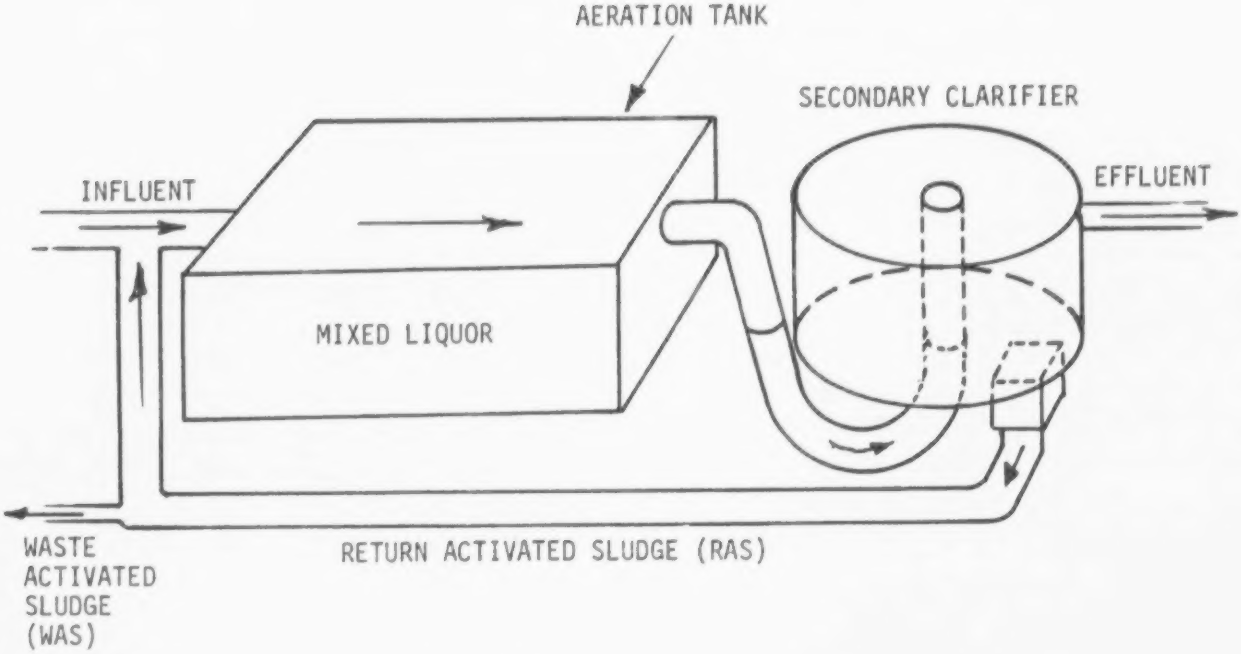

AERATION TANK
SECONDARY CLARIFIER
INFLUENT
EFFLUENT
MIXED LIQUOR
WASTE
ACTIVATED
SLUDGE
(WAS)
RETURN ACTIVATED SLUDGE (RAS)

Fig. 8.2 Activated sludge process

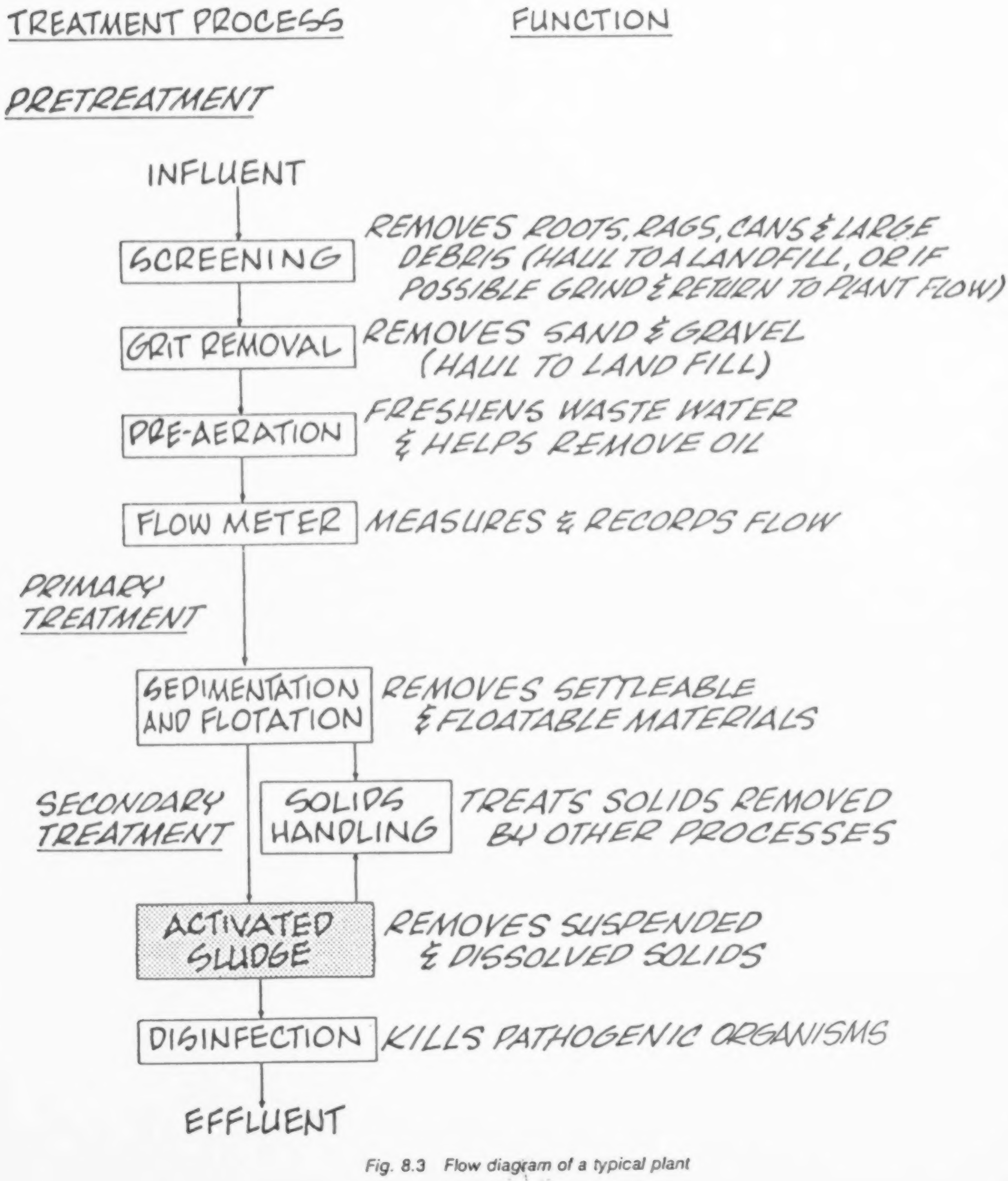

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
ACTIVATED SLUDGE
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
EFFLUENT

Fig. 8.3 Flow diagram of a typical plant

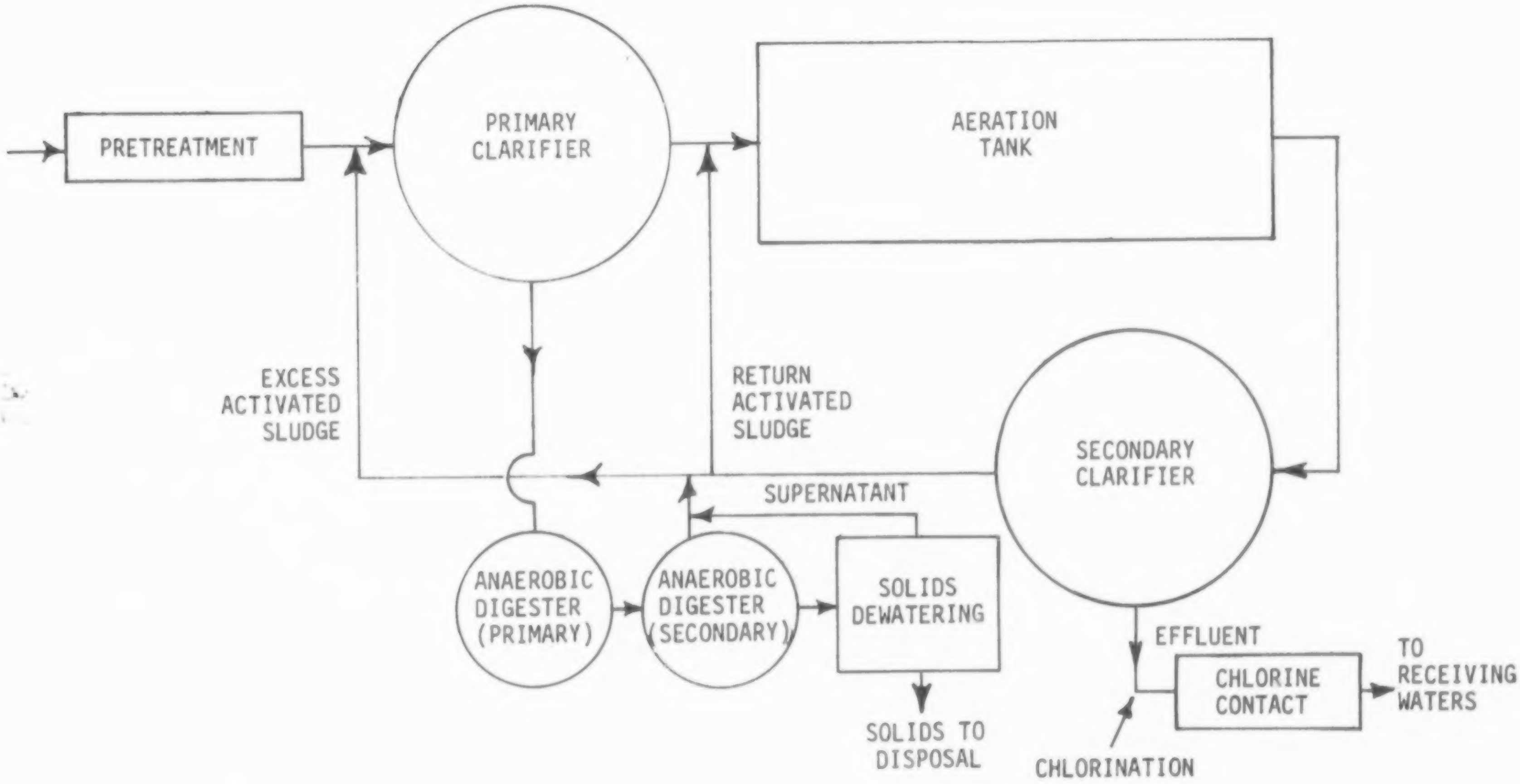

PRETREATMENT
PRIMARY CLARIFIER
AERATION TANK
EXCESS ACTIVATED SLUDGE
RETURN ACTIVATED SLUDGE
SECONDARY CLARIFIER
SUPERNATANT
ANAEROBIC DIGESTER (PRIMARY)
ANAEROBIC DIGESTER (SECONDARY)
SOLIDS DEWATERING
SOLIDS TO DISPOSAL
EFFLUENT
CHLORINE CONTACT
TO RECEIVING WATERS
CHLORINATION

Fig. 8.4 Plan layout of a typical activated sludge plant

Organisms tend to increase with waste (food) load and time spent in the aeration tank. Under favorable conditions the operator will remove (sludge wasting) the excess organisms to maintain the required number of workers for effective waste treatment. Therefore, removal of organisms from the treatment process (sludge wasting) is a very important control technique.

Oxygen, usually supplied from air, is needed by the living organisms for oxidation of wastes to obtain energy for growth. Insufficient oxygen will slow down aerobic organisms, make *FACULTATIVE*[6] organisms work less efficiently, and favor production of foul-smelling intermediate products of decomposition and incomplete reactions.

An increase in organisms in an aeration tank will require greater amounts of oxygen. More food in the influent encourages more organism activity and more oxidation; consequently, more oxygen is required in the aeration tank. An excess of oxygen is required for complete waste stabilization. Therefore, the dissolved oxygen (DO) content in the aeration tank is an essential control test. Some minimum level of oxygen must be maintained to favor the desired type or organism activity to achieve the necessary treatment efficiency. If the DO in the aeration tank is too low, *FILAMENTOUS BACTERIA*[7] will thrive and the sludge *FLOC*[8] will not settle in the secondary clarifier. Also, if the DO is too high, pinpoint floc will develop and not be removed in the secondary clarifier. Therefore, the proper DO level must be maintained so solids will settle properly and the plant effluent will be clear.

Flows must be distributed evenly among two or more similar treatment units. If your plant is equipped with a splitter box or a series of boxes, it will be necessary to periodically check and estimate whether the flow is being split as intended.

Activated sludge solids concentrations in the aerator and the secondary clarifier should be determined by the operator for process control purposes. Solids are in a deteriorating condition as long as they remain in the secondary clarifier. Depth of sludge blanket in the secondary clarifier and concentrations of solids in the aerator are very important for successful wastewater treatment. Centrifuge tests will give a quick estimate of solids concentrations and locations in the units. Precise solids tests should be made periodically for comparison with centrifuge solids tests. Before any changes are made in the mode of operation, precise solids measurements should be obtained. Settleability tests show the degree and volume of solids settling that may be obtained in a secondary clarifier; however, visual plant checks show what is actually happening.

Primary clarifiers are designed to remove material that settles to the bottom or floats to the top. Activated sludge helps this process along by collecting and *AGGLOMERATING*[9] the tiny particles in the primary effluent or raw wastewater so that they will settle better. If for some reason the organisms fail to make this change in the soluble solids, then the secondary clarifier effluent quality will not be satisfactory. For the activated sludge process to work properly, the operator must control the number of organisms, the dissolved oxygen in the aeration tanks, and the treatment time. When these factors are under proper control, the organisms will convert soluble solids and agglomerate the fine particles into a floc mass.

A floc mass is made up of millions of organisms (10^{12} to 10^{18}/100 ml in a good activated sludge), including bacteria, fungi, yeast, protozoa, and worms. When a floc mass is returned to the aerator from the final clarifier, the organisms grow as a result of taking food from the inflowing wastewater. The surface of the floc mass is irregular and promotes the transfer of wastewater pollutants into the solids by means of mechanical entrapment, absorption, adsorption, or adhesion. Many substances not used as food also are transferred to the floc mass, thus improving the quality of the plant effluent.

Material taken into the floc mass is partially oxidized to form cell mass and oxidation products. Ash or inorganic material (silt and sand) taken in by the floc mass increase the density of the mass. Mixing the contents of the aerator causes the floc masses to bump into each other and form larger clumps. Eventually these masses become heavy enough to settle to the bottom of the secondary clarifier where they can be removed easily. This sludge now contains most of the organisms and waste material that had been mixed in the wastewater.

The next step in the activated sludge process is removal of sludge from the secondary clarifier. Some of the material is converted and released to the atmosphere in the form of stripped gases (carbon dioxide or other volatile gases not converted and released in the aeration tank). That leaves water and sludge solids. A certain amount of the solids (waste activated sludge) will be returned to the aerator to treat incoming wastewater. The operator must pump these solids to the aerator. The rest of the waste activated sludge must be removed and disposed of so that it does not continue in the plant flow. After the sludge solids have been removed from the final clarifier, the treated wastewater moves to advanced waste treatment processes and/or the disinfection process.

The successful operation of an activated sludge plant requires the operator to be aware of the many factors influencing the process and to check them repeatedly. To keep the organisms working in the activated sludge, you *MUST* provide a suitable environment. High concentrations of acid, bases, and other toxic substances are undesirable and may kill the working organisms. Uneven flows of wastewater may cause overfeeding, starvation, and other problems that upset the activated sludge process. Failure to supply enough oxygen can cause an unfavorable environment which results in decreased organism activity.

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[6] *Facultative (FACK-ul-tay-tive). Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, facultative bacteria can live under aerobic or anaerobic conditions.*

[7] *Filamentous Bacteria (FILL-a-MEN-tuss). Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.*

[8] *Floc. Groups or clumps of bacteria and particles that have come together and formed a cluster. Found in aeration tanks and secondary clarifiers.*

[9] *Agglomerate (a-GLOM-er-ATE). To cause the growing or coming together of small scattered particles into larger flocs or particles which settle rapidly.*

While successful operation of an activated sludge plant involves an understanding of many factors, actual control of the process as outlined in this section is relatively simple. *CONTROL CONSISTS OF MAINTAINING THE PROPER SOLIDS (FLOC MASS) CONCENTRATION IN THE AERATOR FOR THE WASTE (FOOD) INFLOW BY ADJUSTING THE WASTE SLUDGE PUMPING RATE AND REGULATING THE OXYGEN SUPPLY TO MAINTAIN A SATISFACTORY LEVEL OF DISSOLVED OXYGEN IN THE PROCESS.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 267.

8.0A What is the purpose of the activated sludge process in treating wastewater?

8.0B What is a stabilized waste?

8.0C Why is air added to the aeration tank in the activated sludge process?

8.0D What happens to the air requirement in the aeration tank when the strength (BOD) of the incoming water increases?

8.0E What factors could cause an unsuitable environment for the activated sludge process in an aeration tank?

8.1 REQUIREMENTS FOR CONTROL

Effective control of the activated sludge process depends on the operator's ability to interpret and adjust several interrelated factors. Some of these factors are:

1. Effluent quality requirements.
2. Wastewater flow, concentration, and characteristics of the wastewater received.
3. Amount of activated sludge (containing the working organisms) to be maintained in the process relative to inflow.
4. Amount of oxygen required to stabilize wastewater oxygen demands and to maintain a satisfactory level of dissolved oxygen to meet organism requirements.
5. Equal division of plant flow and waste load between duplicate treatment units (two or more clarifiers or aeration tanks).
6. Transfer of the pollutional material (food) from the wastewater to the floc mass (solids or workers) and separation of the solids from the treated wastewater.
7. Effective control and disposal of inplant residues (solids, scums, and supernatants) to accomplish ultimate disposal in a nonpollutional manner.
8. Provisions for maintaining a suitable environment for the work force of living organisms treating the wastes. Keep them healthy and happy.

Effluent quality requirements may be stated by your regulatory agency in terms of percentage removal of wastes. Current regulations frequently specify allowable quantities of wastes that may be discharged. These quantities are based upon flow and concentrations of significant items such as solids, oxygen demand, coliform bacteria, nitrogen, and oil as specified by your regulatory agencies in your NPDES permit.

The effluent quality requirements in your NPDES permit usually determine what kind of activated sludge operation you can use and how tightly you must control the process. For example, if an effluent containing 50 mg/*L* of suspended solids and BOD (refers to five-day BOD) is satisfactory, a high-rate activated sludge process will probably meet your needs. If the limit is 10 mg/*L*, the high-rate process would not be suitable. If a high degree of treatment is required, very close process control and additional treatment after the activated sludge process may be needed. Today secondary treatment plants are expected to remove 85 percent of the BOD and provide an effluent with a 30-day average BOD of less than 30 mg/*L*.

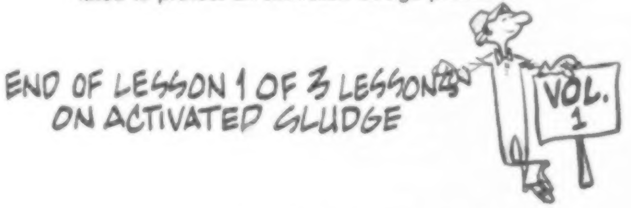
The treatment plant operator has little control over the makeup or amount of influent coming into the treatment plant. However, municipal ordinances may limit or forbid dumping substances into the collection system if they could seriously damage your treatment facilities or create safety hazards. Even with these laws to protect the collection system, some type of inspection program may be necessary (Chapter 27, "Industrial Waste Monitoring"). You may have to work out some additional plans for disposal, pretreatment, or controlled discharge to be sure that substances harmful to your treatment plant are diluted before they enter the plant.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 267.

8.1A What two different ways may effluent quality requirements be stated by regulatory agencies?

8.1B How might harmful industrial waste discharges be regulated to protect an activated sludge process?


END OF LESSON 1 OF 3 LESSONS
ON ACTIVATED SLUDGE
VOL. 1

Please answer the discussion and review questions before continuing with Lesson 2.

DISCUSSION AND REVIEW QUESTIONS

Chapter 8. ACTIVATED SLUDGE

(Lesson 1 of 3 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook before continuing.

1. Sketch the activated sludge process.
2. Define activated sludge.
3. Define facultative bacteria.
4. Some activated sludge plants do not have a primary clarifier. True or False?
5. What happens if the activated sludge retention time is too long in the final clarifier?
6. How can the operator control the activated sludge process?

CHAPTER 8. ACTIVATED SLUDGE

(Lesson 2 of 3 Lessons)

8.2 PACKAGE PLANTS (Extended Aeration)

8.20 Purpose of Package Plants

8.200 Use of Package Plants

You may be assigned to operate a small extended aeration plant (Fig. 8.5). You may not have laboratory facilities and may not be supplied materials for simple tests, such as dissolved oxygen (DO), pH, or settleable solids. Fortunately, this type of plant is usually under a light load and/or sized for along retention of the solids (extended aeration), and the *SLUDGE AGE*[10] may be ten to twenty days (lower ages are associated with higher temperatures). The operation of these plants is similar to the operation of any other activated sludge plant. A high quality effluent requires attention, understanding, and good plant operation.

This type of plant comes in many sizes, but basically there are just two compartments or tanks made from one large tank. The larger compartment is used for aeration, and the smaller one for clarification and settling. Usually provisions are not made for a primary settling compartment. The plant may be mechanically aerated or a small air compressor may provide air through diffusers. The settling tank is usually a double-hopper tank equipped with a pump or *AIR-LIFT*[11] system for the return of sludge from the hoppers of the settling tank back to the aeration tank. Some plants have a third compartment that is used for *AEROBIC DIGESTION*[12] (Fig. 8.6).

8.201 Types of Package Plant Treatment Processes (Fig. 8.7)

The most common types of treatment processes are the extended aeration type, the contact stabilization type, and the complete mix type. These processes are essentially modifications to the conventional activated sludge process and describe the structural arrangement of the aeration tank as well as the various arrangements of process streams that are used to provide process flexibility. Realistically, almost all package plants are of the extended aeration type. They have long solids retention times, high mixed liquor suspended solids and low food/microorganism ratios.

1. Extended Aeration

   Extended aeration is similar to conventional activated sludge except that the bugs are retained in the aeration tank longer and do not get as much food. The bugs get less food because there are more of them to feed. Mixed liquor suspended solids concentrations are from 2,000 to 5,000 mg/L. In addition to the bugs consuming the incoming food, they, in turn, consume any stored food in the dead bugs. The new products are carbon dioxide, water, and a biologi-

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[10] *Sludge Age. A measure of the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process.*

$$\text{Sludge Age, days} = \frac{\text{Suspended Solids Under Aeration, lbs or kg}}{\text{Suspended Solids Added, lbs/day or kg/day}}$$

[11] *Air-Lift. A special type of pump. This device consists of a vertical riser pipe submerged in the wastewater or sludge to be pumped. Compressed air is injected into a tail piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An air-lift pump works similar to the center stand in a percclator coffee pot.*

[12] *Aerobic Digestion (AIR-O-bick). The breaking down of wastes by microorganisms in the presence of dissolved oxygen. Waste sludge is placed in a large aerated tank where aerobic microorganisms decompose the organic matter in the sludge. This is an extension of the activated sludge process.*

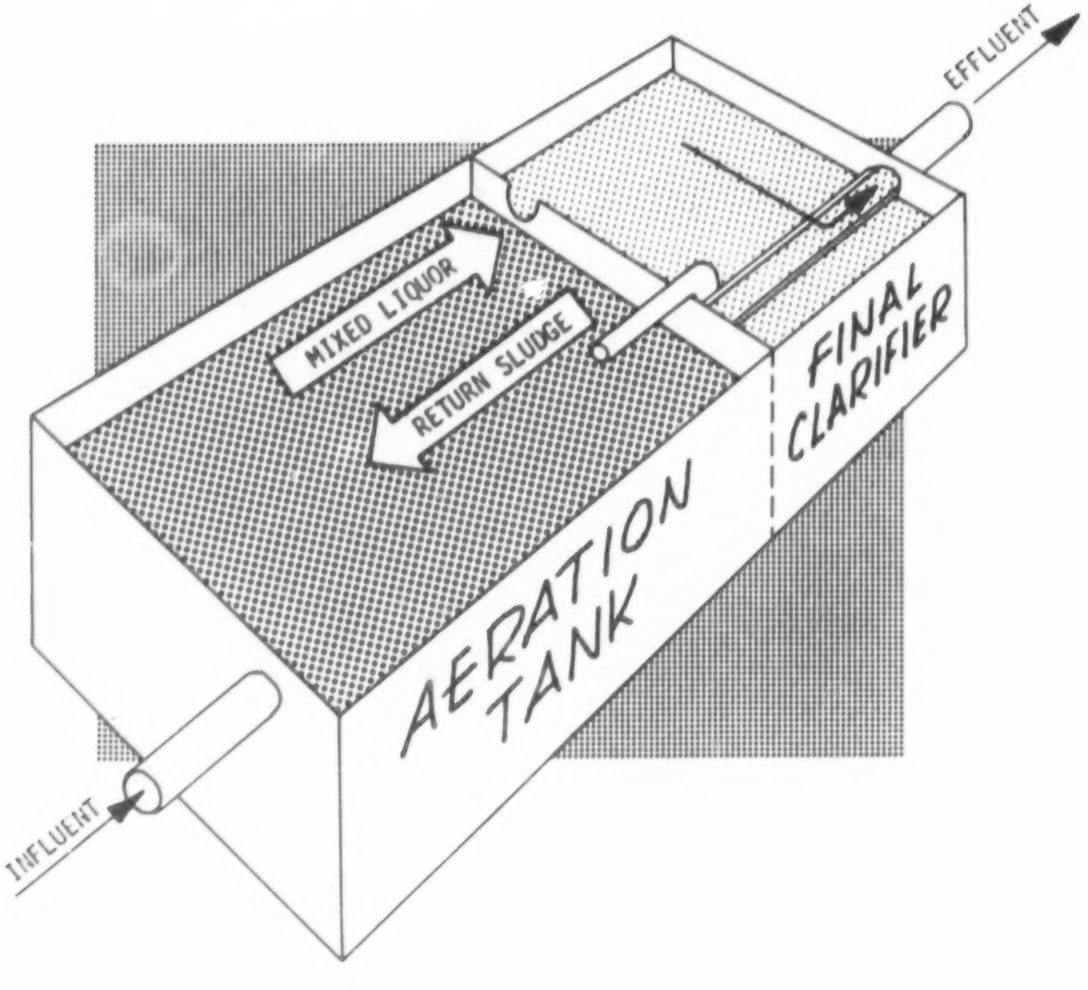

EFFLUENT
MIXED LIQUOR
RETURN SLUDGE
FINAL CLARIFIER
AERATION TANK
INFLUENT

Fig. 8.5 Package plant (two compartments)

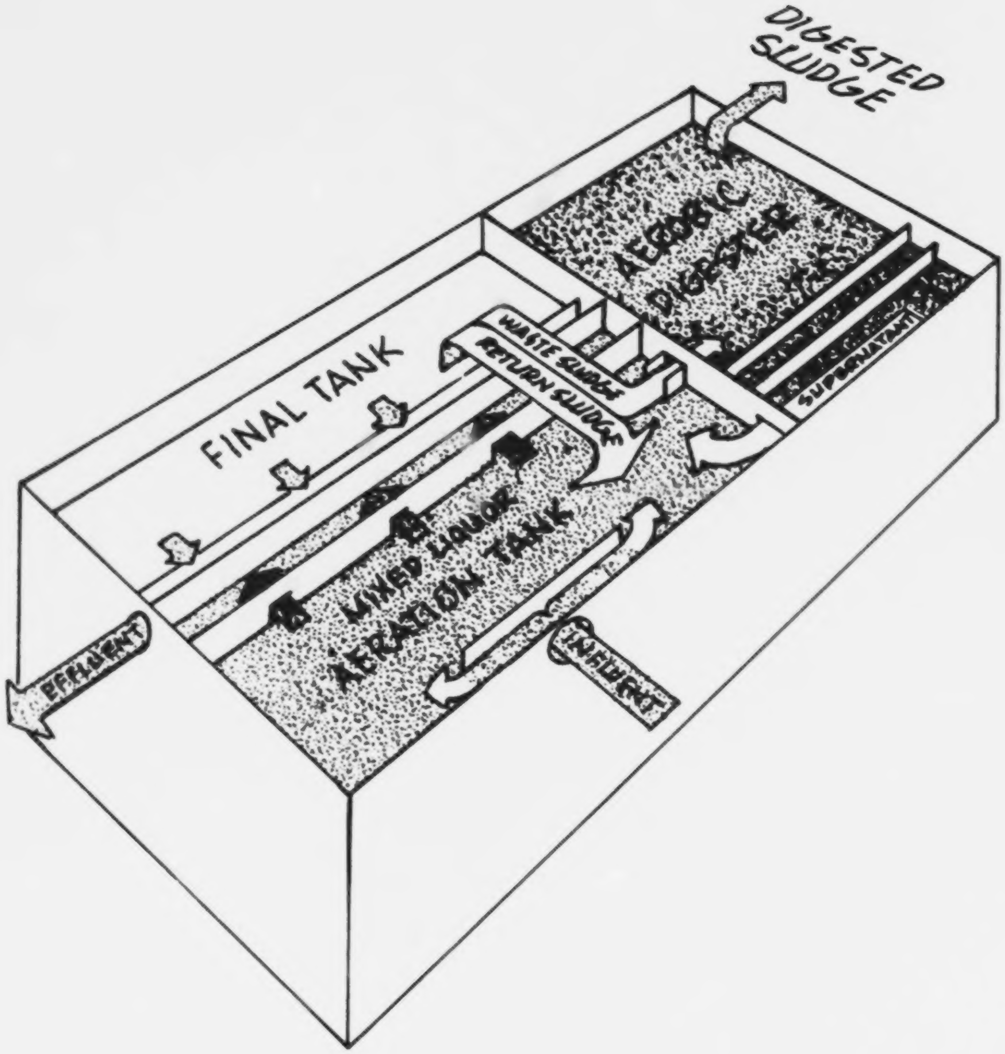
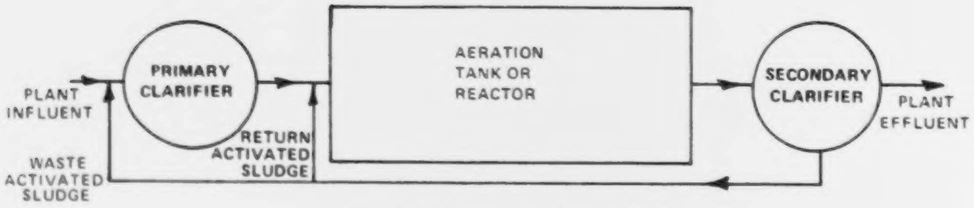
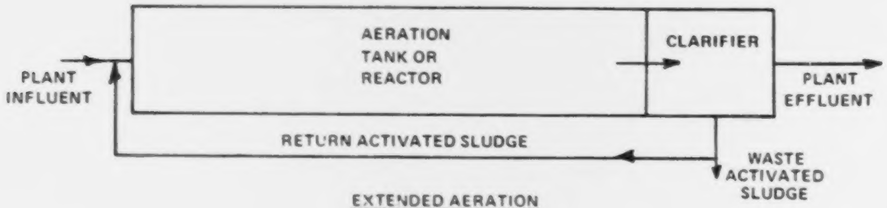

DIGESTED SLUDGE
AEROBIC DIGESTER
WASTE SLUDGE
RETURN SLUDGE
SUPERNATANT
FINAL TANK
MIXED LIQUOR AERATION TANK
EFFLUENT
INFLUENT

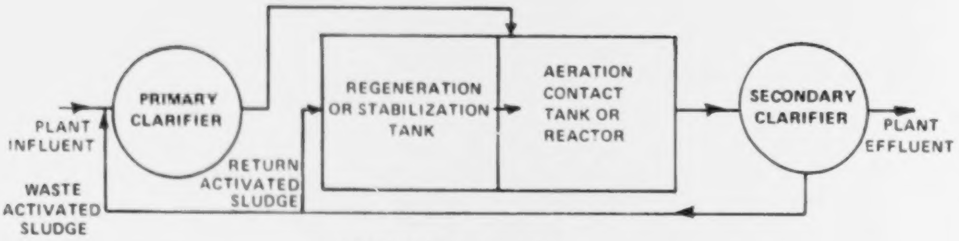
Fig. 8.6 Package plant (three compartments)


PRIMARY CLARIFIER
AERATION TANK OR REACTOR
SECONDARY CLARIFIER
PLANT INFLUENT
PLANT EFFLUENT
RETURN ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE

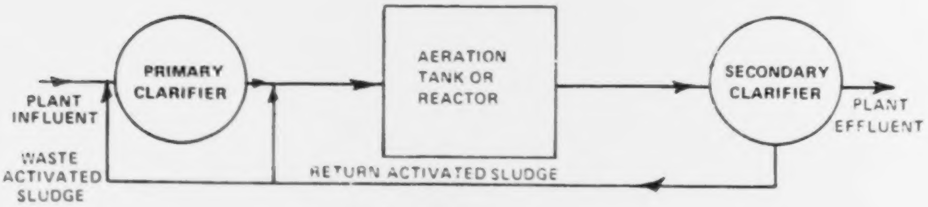
CONVENTIONAL ACTIVATED SLUDGE


AERATION TANK OR REACTOR
CLARIFIER
PLANT INFLUENT
PLANT EFFLUENT
RETURN ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE

EXTENDED AERATION


PRIMARY CLARIFIER
REGENERATION OR STABILIZATION TANK
AERATION CONTACT TANK OR REACTOR
SECONDARY CLARIFIER
PLANT INFLUENT
PLANT EFFLUENT
RETURN ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE

CONTACT STABILIZATION


PRIMARY CLARIFIER
AERATION TANK OR REACTOR
SECONDARY CLARIFIER
PLANT INFLUENT
PLANT EFFLUENT
WASTE ACTIVATED SLUDGE
RETURN ACTIVATED SLUDGE

COMPLETE MIX

NOTE: ALL FOUR PLANTS HAVE AERATION HEADERS RUNNING THE LENGTH OF THE AERATION TANK. COMPLETE MIX ALSO HAS AERATION HEADERS RUNNING ACROSS THE AERATION TANK AT REGULAR INTERVALS.

Fig. 8.7 Types of package aeration plants

cally inert residue. Extended aeration does not produce as much waste sludge as other processes; however, wasting still is necessary to maintain proper control of the process.

2. Contact Stabilization

Contact stabilization is similar to conventional activated sludge except that the capture of the waste material and the digestion of that material by the bugs is done in different aeration tanks. The bugs can "adsorb" the waste material on the cell wall in only fifteen to thirty minutes, but it takes several hours to "absorb" the material through the cell wall.

In conventional activated sludge, adsorption and absorption are done in one tank, therefore, the wastewater has to remain there for a longer time. In both cases, the bugs flow to the clarifier to be separated from the wastewater, but in contact stabilization the settled bugs still have to digest their food. Another aeration tank called a stabilization or re-aeration tank is provided separately for this step. Here the bugs digest the food and then are returned hungry to the original aeration tank (contact tank) ready to eat more food. The mixed liquor suspended solids (MLSS) concentration of the contact tank should be maintained around 1,500 to 2,000 mg/*L*. If the MLSS gets too high, the sludge that the microorganisms form is disposed of or "wasted" as in conventional activated sludge.

In most package plants the adsorption/oxidation is achieved in one tank.

3. Complete Mix

In an ideal complete-mix activated sludge plant, the contents of the tank are completely mixed (the MLSS are uniformly mixed throughout the entire aeration tank). In order to ensure that this is achieved, special arrangements are often employed to *UNIFORMLY DISTRIBUTE THE INFLUENT AND WITHDRAW THE EFFLUENT FROM THE AERATION TANK*. Attention to the tank shape and to intensive mixing is important. There are some means which the operator may use to evaluate the degree to which a particular process operates in the complete mix mode. First and foremost, the entire contents of the tank should be as uniform as possible. This can be confirmed by measurements of DO and suspended solids. If the tank is thoroughly mixed, these measurements should be nearly uniform. The settleability of the complete-mix sludges is generally well within the accepted range of normal operation. The MLSS in the aeration tank ranges from 2,000 to 5,000 mg/*L*.

Most package plants have one influent line and one influent port. The aeration compartment has one aeration header and the tank contents are completely mixed in a very short time. A limitation of the complete mix type is that the process may be more susceptible to short-circuiting.

8.202 Aeration Methods

Two methods are commonly used to supply oxygen from the air to the bacteria — *MECHANICAL AERATION* and *DIFFUSED AERATION*. Both methods are mechanical processes with the difference being whether the mechanisms are at or in the aerator or at a remote location.

Mechanical aeration devices agitate the water surface in the aerator to cause spray and waves by paddle wheels (Fig. 8.8), mixers, rotating brushes, or some other method of splashing water into the air or air into the water where the oxygen can be absorbed.

Mechanical aerators in the tank tend to be lower in installation and maintenance costs. Usually they are more versatile in terms of mixing, production of surface area of bubbles, and oxygen transfer per unit of applied power.

Diffused air systems use a device called a diffuser (Fig. 8.9) which is used to break up the air stream from the blower system into fine bubbles in the mixed liquor. The smaller the bubble, the greater the oxygen transfer due to the greater surface area of rising air bubbles surrounded by water. Unfortunately, fine bubbles will tend to regroup into larger bubbles while rising unless they are broken up by suitable mixing energy and turbulence.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.2A How many compartments are there in a typical package extended aeration plant? What is the purpose of each compartment?

8.2B What are some common characteristics of all package aeration plants?

8.21 Pre-Start Check-Out

If the plant is being installed, a hole is dug large enough to accommodate the plant. Usually the plant is brought to the site by truck and placed in the excavation (hole) by a crane. The inlet sewer and discharge lines are connected and the plant is ready for service after power has been connected.

While the tank is empty, check the following:

1. Tank must be level from one end to the other.
2. If the tank is constructed of metal, is *CATHODIC PROTECTION*[13] required?
3. Condition of paint on exterior and interior.
4. Removal of all rocks and debris from both compartments.
5. If equipped with comminutor or grinder, check lubrication, clearance of cutters, and operation.
6. Check aeration device:
    a. Lubrication
    b. Direction of rotation
    c. Mechanical aeration — proper agitator depth
    d. Compressor, if diffused air
        (1) Air filter and oil bath
        (2) Air header and valves
        (3) Air lift tubes and valves
        (4) Diffusers installed
        (5) Swing header lifts easily and free
7. Record and file the following data:
    a. Plant model and serial number
    b. Two copies of plant operation and maintenance manual
    c. Name plate data from equipment
        (1) Comminutor
        (2) Comminutor motor
        (3) Aeration motor
        (4) Compressor or agitator
        (5) Amperage of running equipment
        (6) Oils and greases specified for each unit
8. Check influent gate or valve for proper operation.

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[13] *Cathodic Protection (ca-THOD-ick). An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.*

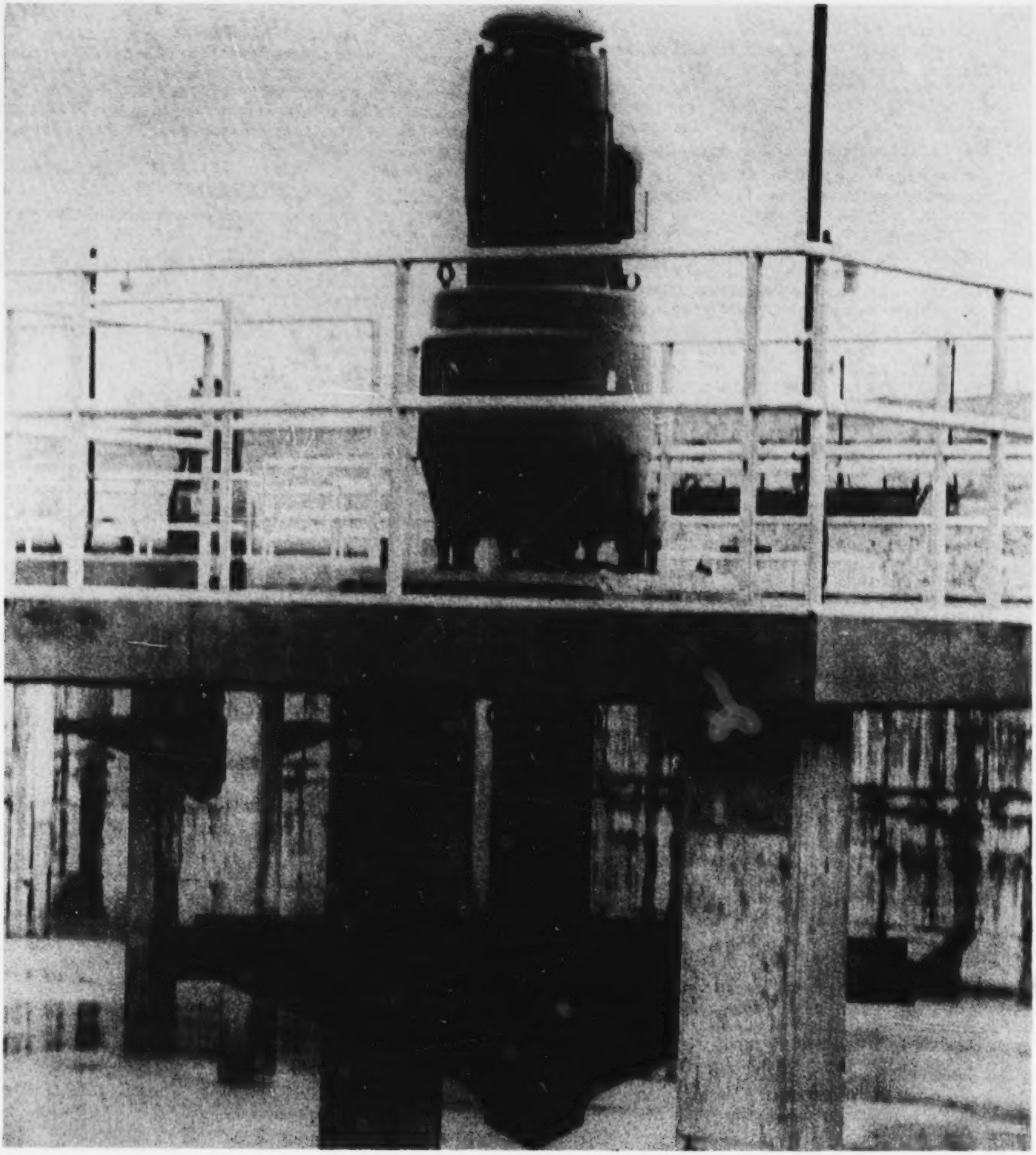

Fig. 8.8 Mechanical aeration device

(Permission of INFILCO INC.)

Fig. 8.9 Air diffuser

(Courtesy Paul Hallbach, National Training Center, Water Quality Office/EPA)

8.22 Starting the Plant

(See Volume II, Chapter 11, for detailed instructions.) As soon as the aeration compartment is full of wastewater, the aerator compressor or agitator may be started. If the plant is the diffused-air type with air-lifts for return sludge, the air line valve to the air-lifts will have to be closed until the settling compartment is filled. Otherwise all the air will attempt to go to the empty compartment and none will go to the diffusers. Once the settling compartment is filled from the overflow from the aeration tank, the air lift valves may be opened. They will have to be adjusted to return a constant stream of water and solids to the aeration tank. This adjustment is usually two to three turns open on the air valve to each air lift.

There may be a buildup of foam during the first week or so of start-up. A one-inch (25 mm) water hose with a lawn sprinkler may be used to keep it under control until sufficient mixed liquor solids are obtained.

8.23 Operation of Aeration Equipment

Aeration equipment should be operated continuously. In a diffused air system, the operator controls air flow to the diffuser with the header control valve. This valve forces excess air to the air lifts in the settling compartment. Good treatment rarely results from interrupted operation and should not be attempted. You can judge how well the aeration equipment is working by the appearance of the water in the settling compartment and the effluent that goes over the weir. If the water is murky or cloudy and the aeration compartment has a rotten egg odor (H_2S), not enough air is being supplied. The air supplied or aeration rate should be increased. If the water is clear in the settling compartment, the aeration rate is probably sufficient. Try to maintain a DO level of around 2 mg/*L* throughout the aeration tank if you have a DO probe or lab equipment to measure the DO. Try to measure the DO at different locations in the aeration tank as well as from top to bottom.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.2C Why should package plants have cathodic protection?

8.2D Why should the valve to the air lift pumps be closed until the settling compartment is filled?

8.2E What whould you do if the water in the aeration compartment was murky or cloudy and the aeration compartment had a rotten egg odor (H_2S)?

8.24 Wasting Sludge

Many older package plants did not come equipped with facilities for wasting sludge. The reason was that the extended aeration system was considered capable of stabilizing the influent suspended solids to a level sufficient for a tolerable release to the receiving waters. Experience has shown that this concept was wrong and that some sludge must be wasted routinely to allow optimum plant performance. The operator must waste a portion of the plant solids content out of the system periodically. For best results, in terms of effluent quality, waste about five percent of the solids each week during summer operation to prevent excessive solids "burping."

To waste the excess activated sludge, turn off the return pumps or air lifts for one hour and continue to let the rest of the plant function. After one hour of not returning sludge, about five percent of the waste solids in the settling compartment are pumped out with a portable pump to a sand or soil drying bed. The amount of solids pumped is determined by measuring the depth of the sludge blanket and then lowering it five percent. Record the pumping time and weekly waste solids for this time period if results are satisfactory.

If your package activated sludge plant does not have an aerobic digester, applying waste activated sludge to drying beds may cause odor problems. If odors from waste sludge drying beds are a problem, consider the following solutions:

1. Waste the excess activated sludge into an aerated holding tank. This tank can be pumped out and the sludge disposed of in an approved sanitary landfill. If aerated long enough, the sludge could be applied to drying beds.
2. The excess or waste activated sludge can be removed by a septic tank pumper and disposed of in an approved sanitary landfill.
3. Arrange for disposal of the excess activated sludge at a nearby treatment plant.

Annually, check the bottom of the hoppers for rocks, sticks, and grit deposits. Also check the tail pieces of the air lifts to be sure that they are clear of rags and rubber goods and in proper working condition.

Frequency and amount of wasting may be revised after several months of operation by examining:

1. The amount of carryover of solids in the effluent.
2. The depth to which the solids settle in the aeration compartment when the aeration device is off (should be greater than one-third of the distance from top to bottom).
3. The appearance of floc and foam in the aeration compartment as to color, settleability, foam make-up, and excess solids on water surface of the tank.
4. Results of laboratory testing (Section 8.26, page 252).

A white, fluffy foam indicates low solids content in the aerator, while a brown, leathery foam suggests high solids concentrations. If you notice high effluent solids levels at the same time each day, the solids loading may be too great for the final clarifier. Excessive solids indicate the mixed liquor suspended solids concentration is too high for the flows and more solids should be wasted.

8.25 Operation

8.250 Normal Operation

Package activated sludge plants should be checked every day. Each visit should include the following:

1. Check the appearance of aeration and final clarification compartment.
2. Check aeration unit for proper operation and lubrication.
3. Check return sludge line for proper operation. If the air lift is not flowing properly, briefly close the outlet valve which forces the air to go down and out the tail piece. This will blow it out and clear any obstructions. Reopen the discharge valve and adjust to desired return sludge flow.
4. Check comminuting device for lubrication and operation.
5. Hose down aeration tank and final compartment.
6. Brush weirs when necessary.
7. Skim off grease and other floating material such as plastic and rubber goods.

8. Check plant discharge for proper appearances, grease, or material of wastewater origin that is not desirable.

8.251 Abnormal Operation

Remember that changing conditions or abnormal conditions can upset the microorganisms in the aeration tank. As the temperature changes from season to season, the activity of the organisms speeds up or slows down. Also the flows and waste (food as measured by BOD and suspended solids) in the plant influent changes seasonally. All of these factors require the operator to gradually adjust aeration rates, return sludge rates and wasting rates. Abnormal conditions may consist of high flows or solids concentrations as a result of storms or weekend loads. These problems require the operator and the plant to be prepared and to do the best possible job with available facilities.

Toxic wastes such as pesticides, detergents, solvents or high or low pH levels can upset or kill the microorganisms in the aeration tank. Plant effluent usually does not deteriorate until after the toxic substance has passed through the plant. To correct problems from toxic substances, try to locate the source and prevent future discharges. If the microorganisms in the aeration tank have been killed, try to build up the microorganisms as if you were working with a new plant.

An outstanding example of a toxic substance added by operators is the uninhibited use of chlorine for odor control (prechlorination). Chlorination is for disinfection. Chlorine is a toxicant and should not be allowed to enter the activated sludge process because it is not selective with respect to type of organisms damaged. It may kill the organisms that you should be retaining as workers. Chlorine is effective in disinfecting the plant effluent *AFTER* treatment by the activated sludge process.

8.252 Troubleshooting

When problems develop in the activated sludge process, try to identify the problem, the cause of the problem, and select the best possible solution. Remember that the activated sludge process is a biological process and may require from 3 days to a week or longer to show any response to the proper corrective action. Allow 7 or more days for the process to stabilize after making a change in the treatment process.

1. Solids in the effluent.
    a. If effluent appears turbid (muddy or cloudy), the return activated sludge pumping rate is out of balance. Try increasing the return sludge rate. Also consider the possibility of something toxic to the microorganisms or a hydraulic overload washing out some of the solids.

    b. If the activated sludge is not settling in the clarifier (sludge bulking), several possible factors could be causing this problem. Look for too low a solids level in the system, strong stale septic influent, high grease levels in influent, or alkaline wastes from a laundry.

    c. If the solids level is too high in the sludge compartment of the secondary clarifier, solids will appear in the effluent. Try increasing the return sludge pumping rate.

    d. If odors are present and aeration tank mixed liquor appears black as compared with the usual brown color, try increasing aeration rates and look for septic dead spots.

    e. If light-colored floating sludge solids are observed on the clarifier surface, try reducing the aeration rates. Try to maintain the dissolved oxygen at around 2 mg/*L* throughout the entire aeration tank.

2. Odors
    a. If the effluent is turbid and the aeration tank mixed liquor appears black as compared with the usual brown color, try increasing aeration rates and look for septic dead spots.

    b. If clumps of black solids appear on the clarifier surface, try increasing the return sludge rate. Also be sure the sludge return line is not plugged and that there are no septic dead spots around the edges or elsewhere in the clarifier.

    c. Examine method of wasting and disposing of waste activated sludge to be sure this is not the source of the odors.

    d. Poor housekeeping could result in odors. Do not allow solids to accumulate or debris removed from wastewater to sit around the plant in open containers.

3. Foaming/Frothing
    a. If too much activated sludge was wasted, reduce wasting rate.

    b. If overaeration caused excessive foaming, reduce aeration rates.

    c. If plant is recovering from overload or septic conditions, allow time for recovery.

    Foaming can be controlled by water sprays until the cause is corrected by reducing or stopping wasting and building up solids levels in the aeration tank.

To learn more about the operation of an activated sludge process under both normal and abnormal conditions, you may refer to Volume II, Chapter 11, "Activated Sludge." There you will also find a troubleshooting guide for activated sludge plants.

8.253 Shutdown

Shutdown procedures depend on whether the plant is being shut down because of operational problems, for maintenance and repairs or for the off-season such as would be the case in a resort area. Activated sludge microorganisms (like people) die quickly from lack of oxygen if the aeration system is out of service for a short time period. Whenever the tank must be drained, try to determine the ground water level. A high ground water level can float a tank and cause considerable damage to structures and pipes. Diffusers should be clean before the tank is returned to service. If the package plant is shut down during the off-season, "mothball" the equipment to prevent damage from weather and moisture. Exact procedures will depend on location and climate.

8.254 Operational Strategy

This section provides a brief summary of the basic concepts in the operation and control of the activated sludge process as it relates to both package plants and oxidation ditches. The following list outlines items that you the operator must consider in the day-to-day operation of your treatment plant.

1. Do the influent flow characteristics vary significantly during the year? Is your activated sludge process modification adequate to provide suitable treatment for these variations?
2. Is adequate pre-treatment and collection system monitoring being practiced to avoid downstream mechanical or process failure?

3. Are routine solids tests performed (centrifuge, settleability, depth of blanket, visual observations) with results plotted on graphs to assist you in determining if a change in the process mode of operation is necessary?
4. Is suitable aeration time and mixing being provided to allow adequate oxidation, conversion, and floc formation of the solids?
5. Is adequate sludge wasting being practiced to properly maintain a favorable food to microorganism balance throughout the system?
6. If an increase or decrease in organisms results, is the oxygen level adjusted accordingly to maintain proper solids settling and production of a clear final effluent?
7. Is the return sludge flow rate such that it allows for a high concentration of solids which will reduce the amount of water returned to the aerator?
8. Do you visit your plant on a regular basis to observe process conditions, check equipment for proper operation, lubricate and maintain equipment, clean process tanks and related equipment?
9. When a problem develops in your activated sludge process, do you refer to Section 8.252, "Troubleshooting?"
10. Do you avoid injuries by avoiding hazards and following safe procedures?
11. Before leaving your plant for the day, do you make a final and detailed check of the equipment for proper operation, insure that flow rates are set properly, that flow gates are set for possible storm and/or high flow conditions, that timer controlled equipment and equipment alarms are set properly, and that equipment is stored and buildings and gates are properly locked?

8.26 Laboratory Testing

Testing for solids condition may be accomplished by the settling test. Using a quart jar, take a sample from the aeration compartment after the aeration device has been operating for ten to fifteen minutes and fill the jar to the top. Let the jar stand and watch the floc form and settle to the bottom of the jar. At the end of thirty minutes, the jar should be approximately half full of the settled solids, or slightly less, and have a chocolate brown color with clear water above it. The solids should appear granular. If the solids do not settle half way and the water above them is cloudy or murky in appearance, a longer aeration period, more air, or solids wasting is needed. If the solids settle to less than a quarter of the jar's depth and the water above the solids is murky or cloudy, no wasting of solids should be done and the solids level in the aerator should be allowed to increase.

If the solids settle to the bottom of the jar with a clear liquor on top and stay down one hour and come up in two hours, this is an indication of good operation. Solids should never be allowed to remain in the settling compartment longer than two hours. If the solids should rise in one hour, this is an indication usually of too much air, or too many solids. Make a slight adjustment to reduce the air to the aeration compartment or increase the return sludge rate.

Another possible cause of solids rising in one hour could be that there are not enough solids under aeration. When this happens the sludge will rise because of the high respiration (breathing) rate of the overtaxed organisms and the rapid DO depletion caused by these organisms in the settling compartment. Under these circumstances you would want to try to increase or build up the mixed liquor suspended solids. To identify the cause of problems and select the proper solution, you must keep good records and observe what is happening in your plant.

The final clarifier should be equipped with a scum baffle. A properly operated plant will produce some light, oxidizing floc that will float to the surface of the settling compartment. A scum baffle will prevent this flow from leaving the compartment in the plant effluent. The better the treatment, the more likely scum will develop, unless the unit is *SEPTIC*.[14]

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.2F How frequently should a package plant be visually checked by an operator?

8.2G If it becomes necessary to waste sludge, how much and when should it be wasted?

8.2H What should you do if you take a sample in a jar from the aeration compartment and after 30 minutes

a. solids do not settle to the bottom half of the jar?
b. solids settle to the bottom and then float to the top?

8.27 Safety

Operators of wastewater treatment plants have one of the worst safety records in the United States. If you are the operator of a small package plant, you must be extremely careful. Frequently you may be the only person at the plant and there will be no one nearby to come to your rescue or help you if you are hurt or seriously injured. THEREFORE, PRACTICE SAFETY, AVOID HAZARDOUS CONDITIONS AND USE SAFE PROCEDURES.

You can be killed by toxic gases (hydrogen sulfide), electric shock and drowning. Slippery surfaces, falls and attempting to lift heavy objects can cause serious injury. Cuts and bruises can lead to infection and pathogens (disease-causing bacteria) in wastewater can make you sick. Chlorine and dangerous lab chemicals can blind you or seriously burn your skin. Whenever you must enter a confined space or do any electrical troubleshooting, know what you are doing and have help standing by. If you must work alone doing routine operation and maintenance, phone your office at regular intervals and have someone check on you if you fail to report. You can avoid injuries if you avoid hazards and follow safe procedures.

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[14] *Septic (SEP-tick). This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.*

8.28 Maintenance

Maintenance of equipment in package plants should follow the manufacturer's instructions. Items requiring attention include:

1. Plant cleanliness. Wash down tank walls, weirs and channels to reduce the collection of odor-causing materials.
2. Aeration equipment
   a. Air blowers and air diffusion units
   b. Mechanical aerators
3. Air-lift pumps
4. Scum skimmer
5. Sludge scrapers
6. Froth spray system
7. Weirs, gates and valves
8. Raw wastewater pumps

8.29 ADDITIONAL READING

1. *PACKAGE TREATMENT PLANTS OPERATIONS MANUAL,* (EPA 430/9-77-005), April 1977. Obtain from Environmental Quality, Instructional Resource Center, Room 310, 1200 Chambers Road, Columbus, Ohio 43212. Order No. 120U, price $4.43.
   NOTE: This is an outstanding publication and if you are the operator of a package activated sludge plant, you should obtain this Operations Manual.
2. *OPERATORS' POCKET GUIDE TO ACTIVATED SLUDGE — PART II: PROCESS CONTROL AND TROUBLESHOOTING.* Available from CRS SIRRINE, 1177 West Loop South, Suite 600, Houston, TX 77027. Attention: Perdie Daniels. Price $1.50.
3. *ACTIVATED SLUGE PACKAGE PLANT OPERATION MANUAL,* prepared by Minnesota Pollution Control Agency. Available from National Environmental Training Association, 8687 Via de Ventura, Suite 214, Scottsdale, AZ 85258. Price to members, $15.00, and nonmembers, $18.50.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.2I How can operators avoid being injured?

8.2J What safety precautions should be taken if you must work alone?

END OF LESSON 2 OF 3 LESSONS
ON ACTIVATED SLUDGE

Please answer the discussion and review questions before continuing with Lesson 3.

DISCUSSION AND REVIEW QUESTIONS

Chapter 8. ACTIVATED SLUDGE

(Lesson 2 of 3 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 1.

7. What is a temporary way to control foaming in the aeration compartment of a package plant?
8. How would you operate the aeration device in a package plant?
9. How would you waste sludge in a package plant?
10. What items can cause problems for the operator of a package aeration plant?

CHAPTER 8. ACTIVATED SLUDGE

(Lesson 3 of 3 Lessons)

8.3 OXIDATION DITCHES

8.30 Use of Oxidation Ditches

8.300 Flow Path for Oxidation Ditches

The oxidation ditch (Fig. 8.10 and Table 8.1) is a modified form of the activated sludge process and is usually operated in the extended aeration mode.

The main parts of the oxidation ditch are the aeration basin which generally consists of two channels placed side by side and connected at the ends to produce one continuous loop of the wastewater flow, a brush rotor assembly (Fig. 8.11), settling tank, return sludge pump, and excess sludge handling facilities.

There is usually no primary settling tank or grit removal system used in this process. Inorganic solids such as sand, silt and cinders are captured in the oxidation ditch and removed during sludge wasting or cleaning operations. The raw wastewater passes directly through a bar screen to the ditch. The bar screen is necessary for the protection of the mechanical equipment such as rotor and pumps. Comminutors or barminutors may be installed after the bar screen or instead of a bar screen. The oxidation ditch forms the aeration basin and here the raw wastewater is mixed with previously formed active organisms. The rotor is the aeration device that entrains (dissolves) the necessary oxygen into the liquid for microbial life and keeps the contents of the ditch mixed and moving. The velocity of the liquid in the ditch must be maintained to prevent settling of solids, normally 1.0 to 1.5 feet per second (0.3 to 0.45 m/sec). The ends of the ditch are well rounded to prevent eddying and dead areas, and the outside edges of the curves are given erosion protection.

TABLE 8.1 PURPOSES OF PARTS IN AN OXIDATION DITCH

Part	Purpose
1. Oxidation Ditch	Provides detention time where activated sludge microorganisms treat wastewater.
2. Rotor	Causes surface aeration which transfers oxygen from air to water for respiration by microorganisms. Also keeps the contents of the ditch mixed and moving.
3. Level Control Weir	Regulates how deep rotors sit in the flow of wastewater. This affects the amount of oxygen dissolved in or transferred to the water being treated. Overflow goes to final settling tank.
4. Final Settling Tank	Allows activated sludge to be separated from water being treated. Clear effluent leaves plant and settled activated sludge is either returned to oxidation ditch or wasted.
5. Return Sludge Pump	Returns settled activated sludge from final settling tank to oxidation ditch or to excess sludge handling facilities.
6. Excess Sludge Handling Facilities	Treat waste activated sludge for ultimate disposal.

The mixed liquor flows from the ditch to a clarifier for separation. The clarified water passes over the effluent weir and is chlorinated. Plant effluent is discharged to either a receiving stream, percolation ditches, or a subsurface disposal or leaching system. The settled sludge is removed from the bottom of the clarifier by a pump and is returned to the ditch. Scum which floats to the surface of the clarifier is removed and either returned to the oxidation ditch for further treatment or disposed of by burial.

Since the oxidation ditch is operated as a closed system, the amount of volatile suspended solids will gradually increase. It will periodically become necessary to remove some sludge from the process. Wasting of sludge lowers the MLSS (Mixed Liquor Suspended Solids) concentration in the ditch and keeps the microorganisms more active. Control of sludge concentration and wasting of excess sludge is one of the reasons for the high reductions possible by this process. Excess sludge may be dried directly on sludge drying beds or stored in a holding tank or in sludge lagoons for later disposal to larger treatment plants or approved sanitary landfills.

The basic process design results in simple, easy operation. A high mixed liquor suspended solids (MLSS) concentration, usually between 2,000 to 6,000 mg/*L* (some plants carry 6,000 to 8,000 mg/*L* MLSS), is carried in the ditch and the plant may be capable of handling shock and peak loads without upsetting plant operation. There is no foam problem after solids build up, as experienced with other types of activated sludge plants. Cold weather operation has less effect on plant efficiency than other processes because of the large number of microorganisms in the ditch.

Operating plants in the United States are achieving BOD removals of about 90 percent and as high as 98 percent.

8.301 Description of Oxidation Ditches

1. Plant flow	0.2 to 20.0 MGD (750 to 75,000 cu m/day)
2. BOD loading	10 to 50 lbs BOD/day per 1,000 cubic feet of ditch (200 to 800 kg/day per 1,000 cu m)

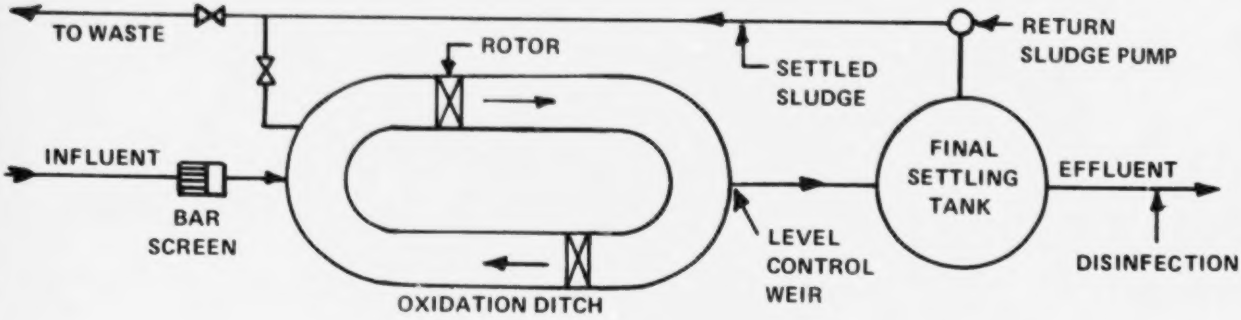
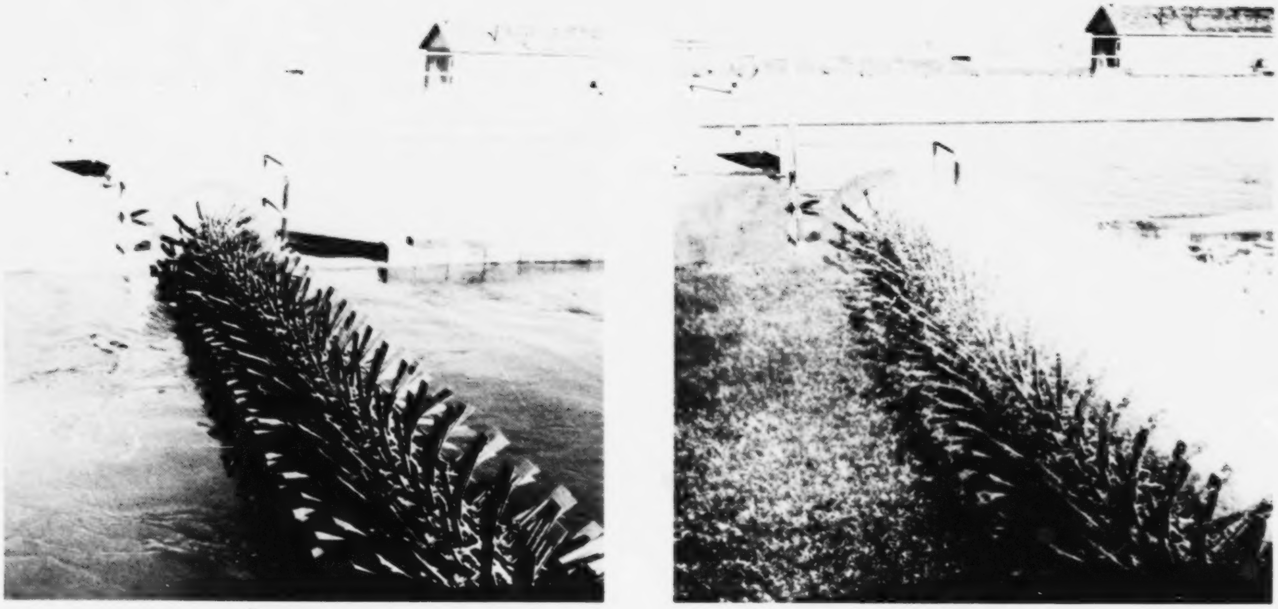

TO WASTE
ROTOR
SETTLED
SLUDGE
RETURN
SLUDGE PUMP
INFLUENT
BAR
SCREEN
FINAL
SETTLING
TANK
EFFLUENT
LEVEL
CONTROL
WEIR
DISINFECTION
OXIDATION DITCH

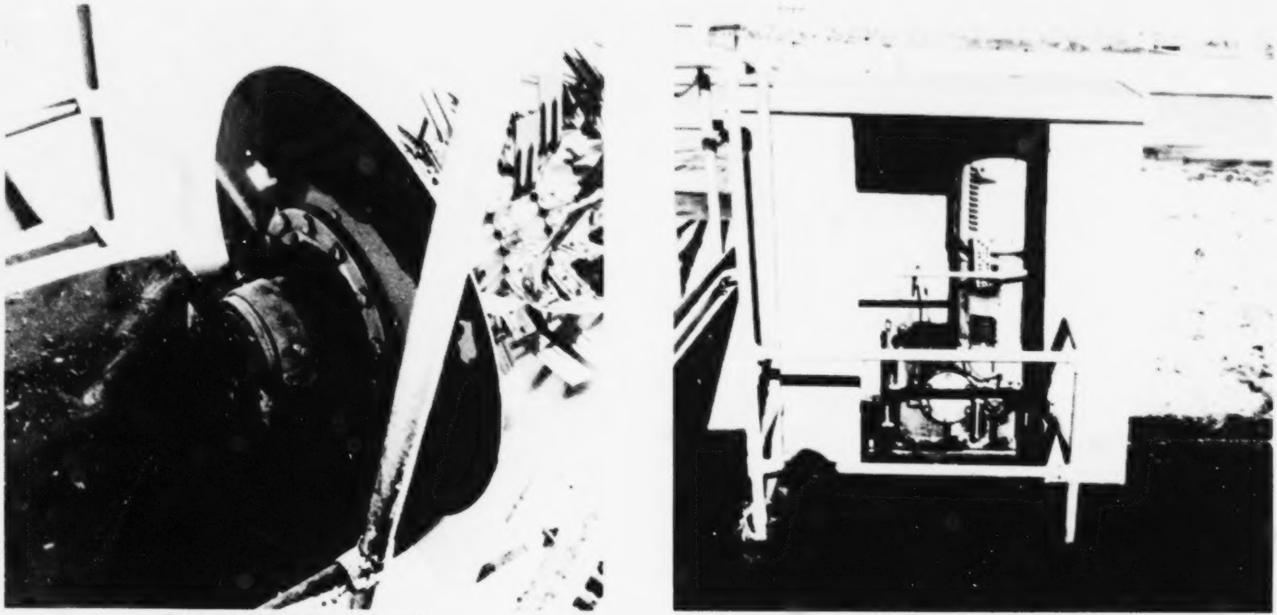
Fig. 8.10 Oxidation ditch plant

Source: "Oxidation Ditch" prepared by William L. Berk for the New England Regional Wastewater Institute, South Portland, Maine 04106 (August 1970).



Brush rotor

Brush rotor



Outboard bearing assembly

Brush rotor drive motor and gear reducer assembly

Fig. 8.11 Brush rotor

3. F/M ratio[15]	0.03 to 0.1 lbs BOD/day/lb MLVSS
4. MLSS concentration	2,000 to 6,000 mg/*L*
5. Sludge age	20 to 35 days
6. Ditch detention time	3 to 24 hours
7. Minimum velocity	1.0 fps (0.3 mps)
8. DO levels	0.5 to 3.0 mg/*L*
9. Liquid level	3.0 to 7.0 feet (1 to 2 m)

See Section 8.35, "Operational Criteria," for procedures to calculate these items. Use of the F/M ratio and Sludge Age to control the activated sludge process will be discussed in Volume II, Chapter 11.

8.31 Safety

Lost time, injury, and even death is the result of not being concerned with applying the rules of safety to all activities involved in operating and maintaining a plant. Practicing "safety" is not just know what to do; it is a life-style. Personnel must not only acquire this "life-style," but must also know what to do if an accident occurs. Refer to Chapter 14, "Safety," for more information.

Some safety precautions that should be observed at all times when working in a treatment plant include:

1. Wear shoes with soles that retard slipping. Cork-inserted composition soles provide the best traction for all-around use.
2. Slippery algal growths should be scrubbed off and washed away whenever they appear.
3. Keep all areas clear of spilled oil or grease. Use soap and water, not gasoline or solvents, for cleaning.
4. Wear gloves when working with equipment or while in direct contact with wastewater.
5. Do not leave tools, equipment and materials where they could create a safety hazard.
6. Adequate lighting should be provided for night work and in areas with limited existing lighting.
7. Ice conditions in winter require spiked shoes and the sanding of icy areas if the ice cannot be thawed away with wash water.
8. Remove only sections of handrails, deck plates or grating necessary for the immediate job. Removed sections should be properly stored out of the way and properly secured against falling.
9. Do not walk on top of the oxidation ditch sidewalls; you may slip and fall into the ditch.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.3A List the major components of an oxidation ditch treatment process.

8.3B Why are the ends of oxidation ditches well rounded?

8.3C Why should operators avoid walking on top of oxidation ditch sidewalls?

8.32 Start-Up

There are two primary objectives of start-up. One is to make certain that all mechanical equipment is operating properly. The second is to develop a proper microbial floc (activated sludge) in the oxidation ditch. This floc development is essential for the plant to succeed in reducing the quantities of polluting materials in the raw wastewater.

The start-up procedures presented here should be used along with the manufacturer's start-up procedures for all components of the plant. The plant operator, the contractor, engineer and equipment manufacturer's representative should all be present at the start-up.

During start-up of the plant, some construction may still be in progress. Special care should be given to insure that all safety procedures are followed at all times.

8.320 Pre-Start Inspection

The inlet structure should be checked for debris and all debris cleaned from the structure prior to start-up.

The ditch structure should be cleaned of all debris prior to start-up. Check the walkways to insure there are no debris that can later fall into the channel. Inspect the influent and effluent lines to be sure that they are free of debris.

If you are preparing to start a rotor that is a new installation, one that has not been in operation for some time, or one that has just been overhauled, a thorough inspection check should be made prior to starting the rotor to prevent damage to the rotor and injury to personnel.

Rotor check list.

1. The "on-off" switch is "OFF" and locked out.
2. Motor secured to gear reducer.
3. Gear reducer assembly secured to the mounting platform.
4. Rotor cylinder shaft secure to reducer coupling bolts.
5. Rotor blades and teeth secure to the cylinder.
6. Driver, rotor, bearings and stand(s) properly aligned.
7. Rotor turns with a reasonable pull on the cylinder.
8. Rotor anti-rotation screws properly adjusted.

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[15] *F/M ratio.* *Food to microorganism ratio.*

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg/L} \times 8.34\ \text{lbs/gal}}{(\text{Ditch Volume, MG} \times \text{SS, mg/L} \times \text{Volatile portion, decimal} \times 8.34\ \text{lbs/gal})}$$

9. Proper oil type and quantity in the reducer.
10. All bearings greased with the proper lubricant.
11. All lube oil line fittings tight.
12. Gear reducer housing air vent "open."
13. All bolts tight.
14. All tools and foreign material are clear of the rotor assembly.
15. Safety guards over moving parts properly installed and secure.

Following completion of the pre-start checks, the rotor assembly is ready to start. Be sure all personnel are clear of the rotor assembly. Turn the main power breaker "ON." The "on-off" switch should now be positioned to "ON" and the rotor will start.

If the rotor assembly is part of a new oxidation ditch installation, the following additional items should be done:

1. Start the rotor(s) with the rotor(s) out of the water.
2. Check and record the motor amperage and voltage on each phase.
3. Check the rotation of the rotor and run the rotor for at least one hour (see "bump start" below).
4. Recheck the rotor support bearing(s) and drive alignment and realign if necessary according to manufacturer's installation drawings.
5. Tighten all nuts, bolts, and set screws to prepare the rotor for regular operation.

Check and record the items noted under 8.330, "Normal Operation, Records, Mechanical."

NOTE: When starting a new or recently overhauled rotor assembly, a "bump start" is recommended *BEFORE* a routine full start and run is attempted.

A "bump start" allows operation of the rotor assembly for 2 to 3 seconds and is accomplished by briefly positioning the "on-off" switch to "ON" and immediately returning it to the "OFF" position.

This short run-time will allow you to determine if the rotor assembly operates freely and properly, operates in the proper rotation, and will avoid extensive damage to the rotor assembly if it is not properly installed.

Make sure the adjustable weir operates freely and does not bind. Set the weir at the proper elevation in accordance with O & M manual or manufacturer's instructions.

The clarifier structure and piping should be inspected and cleared of all debris. All control gates and valves should be checked for smooth operation and proper seating. Refer to Chapter 5, "Sedimentation and Flotation," for proper clarifier start-up procedures.

The return sludge and waste sludge systems should be examined for leakage and all valves should be operated one complete cycle and set for normal operation. Pumps should be manually operated with liquid in them to check proper operation. One pump should be operated and checked for vibration, excess noise, overheating and the amperage reading record. The same procedure should then be repeated for the second pump with the first pump shut off. If your plant has waste sludge treatment facilities (holding tanks, lagoons or drying beds), operate the necessary valves to allow pumping to this part of the plant. Operate each pump manually and note the discharge. Shut both pumps off and return the valves to the normal flow position for returning the settled sludge back to the oxidation ditch.

8.321 Plant Start-Up

Start to fill ditch with water or wastewater. If possible, add a water tank or two full of healthy seed activated sludge from a nearby plant. Divert all wastewater to be treated into ditch. If ditch was initially filled with wastewater and one or two days were required to fill the ditch during hot weather, odor problems could develop. Start rotors when water level reaches bottom of rotor blades.

During plant start-up, a dark gray color of the developing MLSS may be seen. A dark gray color usually indicates a lack of bacterial build-up in the mixed liquor. If this condition continues for more than several days, check your return sludge system to see that it is operating properly.

Once the water reaches the rotors, do not start discharging to the clarifier. Allow the wastewater to continue to fill the ditch and to be treated. When the water level approaches the maximum submergence of the rotors and the peak motor load, then start allowing some of the water to be discharged to the clarifier. During start up an unstable clarifier effluent may result due to the inadequate biological treatment. As this effluent is generally the discharged product (as final effluent), chlorination is to be used to reduce health hazards on the receiving waters during this time. State regulatory agencies should be contacted to insure that the receiving waters will not be harmed as a result of heavily chlorinating the plant effluent.

During the period of start-up, wastewater testing procedures should be initiated as soon as possible. The actual flow rates should be recorded and also the incoming BOD and COD levels.

Building up of the MLSS concentration is the most important activity during the start-up process. At least three and possibly up to fifteen days are required to build up the MLSS concentration. In the event the actual MLSS concentration cannot be determined on a daily basis you should at least record daily the results of the 30-minute sludge settleability tests. See Section 8.26, "Laboratory Testing." During this period, maintain the highest possible return activated sludge rate.

Dissolved oxygen (DO) should be taken at a sampling location approximately 15 feet (4.5 m) upstream from the rotor. Until the desired MLSS concentration is reached and the 30-minute sludge settleability volume reaches 20 percent, a minimum DO concentration of 2.0 mg/*L* should be kept in the ditch. Following this period, a lesser DO concentration may be desired, but never less than 0.5 mg/*L* at a point 15 feet (4.5 m) upstream of the rotors.

Following start-up, when the plant has stabilized, the solids should settle rapidly in the clarifier leaving a clear, odorless and stable effluent. The solids should look like the particles, golden to rich dark brown in color, with sharply defined edges.

You should not expect immediate results from the start-up procedures. Plant start-up takes time, sometimes over a month if a "seed" activated sludge from another treatment plant is not available. Also, some conditions may occur during start up that would, under normal conditions, indicate a poorly operating process such as light foaming in the ditch or a cloudy supernatant in the settleable solids tests. These conditions should only be temporary if the information in this section is applied properly.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.3D What are the two primary objectives of start-up?

8.3E What items or structures should be inspected during the pre-start inspection?

8.3F During plant start-up, when should the rotors be started?

8.3G When an oxidation ditch is operating properly, how should the activated sludge solids appear?

8.33 Operation

8.330 Normal Operation

Process controls and operations of an oxidation ditch are similar to the activated sludge process. To obtain maximum performance efficiency, the following control methods must be maintained:

1. Proper food supply (measured as BOD or COD) for the microorganisms;
2. Proper DO levels in the oxidation ditch;
3. Proper ditch environment (no toxicants, and sufficient microorganisms to treat the wastes);
4. Proper ditch detention time to treat the wastes by control of the adjustable weir; and
5. Proper water/solids separation in the clarifier.

Proper food supply for the microorganisms

Influent flows and waste characteristics are subject to limited control by the operator. Municipal ordinances may prohibit discharge to the collection system of materials damaging to treatment structures or human safety. Control over wastes dumped into the collection system requires inspection to insure compliance. Alternate means of disposal, pretreatment, or controlled discharge of significantly damaging wastes may be required in order to permit dilution to an acceptable level by the time the waste arrives at the treatment plant. Refer to Chapter 27, "Industrial Waste Monitoring," for waste discharge control methods.

Proper DO levels

Proper operation of the process depends on the rotor assembly supplying the right amount of oxygen to the waste flow in the ditch. For the best operation, a DO concentration of 0.5 to 2.0 mg/*L* should be maintained just upstream (15 feet or 4.5 m) of the rotors. Over-oxygenation wastes power and excessive DO levels can cause a pinpoint floc to form which does not settle and is lost over the weir in the settling tank. Control of rotor oxygenation is achieved by adjusting the ditch outlet level control weir.

The level or elevation of the rotors is fixed but the deeper the rotors sit in the water, the greater the transfer of oxygen from the air to the water (greater DO). The ditch outlet level control weir regulates the level of water in the oxidation ditch.

Proper environment

The oxidation ditch process with its long-term aeration basin is designed to carry MLSS concentrations of 2,000 to 6,000 mg/*L*. This provides a large organism mass in the system.

Performance of the ditch and ditch environment can be evaluated by conducting a few simple tests and general observations. The color and characteristics of the floc in the ditch as well as the clearness of effluent should be observed and recorded daily. Typical tests are settleable solids, DO upstream of the rotor, pH and residual chlorine in the plant effluent. These test procedures are outlined in Chapter 16, "Laboratory Procedures and Chemistry." Periodically laboratory tests such as BOD, COD, suspended solids, volatile solids, total solids and microscopic examinations should be performed by the plant operator or an outside laboratory. The results will aid you in determining the actual operating efficiency and performance of the process.

Oxidation ditch solids are controlled by regulating the return sludge rate and waste sludge rate. Remember that solids continue to deteriorate as long as they remain in the clarifier. Adjust the return sludge rate to return the microorganisms in a healthy condition from the final settling tank to the oxidation ditch. If dark solids appear in the settling tank, either the return sludge rate should be increased (solids remaining too long in clarifier) or the DO levels are too low in the oxidation ditch.

Adjusting the waste sludge rate regulates the solids concentration (number of microorganisms) in the oxidation ditch. If the surface of the ditch has a white, crisp foam, reduce the sludge wasting rate. Some plants have operated successfully with an MLSS of 6,000 to 8,000 mg/*L* and very little wasting of solids. If the surface has a thick, dark foam, increase the wasting rate. Waste activated sludge may be removed from the ditch by pumping to a sludge holding tank, to sludge drying beds, to sludge lagoons or to a tank truck. Ultimate disposal may be to larger treatment plants or to approved sanitary landfills.

Remember that this is a biological treatment process and several days may be required before the process responds to operation changes. Make your changes slowly, be patient and observe and record the results. Allow seven or more days for the process to stabilize after making a change. For additional information on the regulation of the process, see Section 8.26, "Laboratory Testing," which discusses the use of the settling test for operational control. For more details on controlling the activated sludge process, see Volume II, Chapter 11.

Proper treatment time

Treatment time is directly related to the flow of wastewater. Velocities in the ditch should be maintained between 1.0 to 1.5 feet per second (0.3 to 0.45 m/sec). With this in mind, the ditch contents should travel the complete circuit of the ditch, or from rotor to rotor, every 3 to 6 minutes.

Proper water/solids separation

MLSS which have entered and settled in the secondary clarifier are continuously removed from the clarifier as return sludge, by pump, for return to the oxidation ditch. Usually all sludge formed by the process and settled in the clarifier is returned to the ditch, except when wasting sludge. Scum which is captured on the surface of the clarifier also is removed from the clarifier and either returned to the oxidation ditch for further treatment or disposed of by burial.

Observations

Some aspects of the operation of your oxidation ditch plant can be controlled and adjusted with the help of some general observations. General observations of the plant are important to help you determine whether or not your oxidation ditch is operating as intended. These observations include color of the mixed liquor in the ditch, odor at the plant site and clarity of the ditch and sedimentation tank surfaces.

COLOR. You should note the color of the mixed liquor in the ditch daily. A properly operating oxidation ditch plant mixed liquor should have a medium to rich dark brown color. If the MLSS, following proper start-up, changes color from a dark brown to a light brown and the MLSS appear to be thinner than before, the sludge waste rate may be too high which may cause the plant to lose efficiency in removing waste materials. By decreasing sludge waste rates before the color lightens too much, you can insure that the plant effluent quality will not deteriorate due to low MLSS concentrations.

If the MLSS becomes black, the ditch is not receiving enough oxygen and has gone "anaerobic." The oxygen output of the rotors must be increased to eliminate the black color and return the process to normal aerobic operation. This is done by increasing the submergence level of the rotor.

ODOR. When the oxidation ditch plant is operating properly, there will be little or no odor. Odor, if detected, should have an earthy smell. If an odor other than this is present, you should check and determine the cause. Odor similar to rotten eggs indicates that the ditch may be going anaerobic, requiring more oxygen. The color of the MLSS could be black if this were the case.

Odor may also be a sign of poor housekeeping. Grease and solids buildup on the edge of the ditch or sedimentation tank will go anaerobic and cause odors. With an oxidation ditch, odors are much more often caused by poor housekeeping than poor operation.

CLARITY. In a properly operating oxidation ditch a "layer" of "clear" water or supernatant is usually visible a few feet upstream from the rotor. The depth of this relatively clear water may vary from almost nothing to as much as two or more inches (5 cm) above the mixed liquor.

Two other good indications of a properly operating oxidation ditch are the clarity of the settling tank water surface and the oxidation ditch surface free of foam buildup. Foam buildup in the ditch (normally not enough to be a nuisance) is usually caused by an insufficient MLSS concentration. Most frequently foam buildup is only seen during plant start-up and will gradually disappear.

Clarity of the effluent from the secondary clarifier discharged over the weirs is the best indication of plant performance. A very clear effluent shows that the plant is achieving excellent pollutant removals. A cloudy effluent often indicates a problem with the plant operation.

RECORDS. Daily, or as scheduled, the items listed below should be checked and a record made of these checks. Accurate records are essential and invaluable in evaluating rotor efficiency and in establishing normal operating conditions.

Check:

ITEM	CONDITION
Mechanical	
1. Motor	High or uneven amperage
2. Motor	High temperature
3. Motor	Unusual noise
4. Motor	Operating hours
5. Gear reducer	Unusual bearing or gear noise
6. Gear reducer	Proper oil level via sight glass or dip stick
7. Gear reducer housing	Air vent pipe "open"
8. Outboard bearing	Unusual bearing noise
9. Rotor	Unusual noise or vibration
10. Rotor	Remove any debris caught in rotor blades such as rags, weeds, or plastic goods.
Operation	
11. DO concentrations	Use portable DO probe or perform Winkler lab test. DO should be taken approximately 15 feet (4.5 m) *UPSTREAM* of the rotor(s). Maintain 0.5 to 2.0 mg/*L* at this point.
12. Ditch velocity	1.0 to 1.5 fps (0.3 to 0.45 mps)
13. Ditch water level	Read staff gage in ditch. Convert this reading to brush aerator submergence.
14. Ditch surface condition	Neither white foam nor a heavy brown scum
15. Mixed Liquor Suspended Solids concentration (MLSS)	2,000 to 5,000 mg/*L*

FINAL PLANT SURVEY. Before leaving for the day, one final inspection should be made around the plant. The following questions may help in seeing that you have left the plant in a condition so that it will be operating properly the next time it is attended.

1. Are there any pieces of equipment that are operating poorly that may have to be checked before the next scheduled day of operator attendance (hot bearings, loose belts)?
2. Are return sludge rates set at the correct level?
3. Are flowmeters clean and operating?
4. Are inlet gates set properly in case of high flows?
5. Has the rotor level of submergence been set properly?
6. If some equipment is time-clock controlled, are the time clocks set?
7. If remote alarms are used to warn someone about equipment failures, are these set properly?
8. Is equipment stored and locked so as to prevent vandalism?
9. Are outside lights on or set to come on?

Performance

Figure 8.12 shows the performance of an actual oxidation ditch.

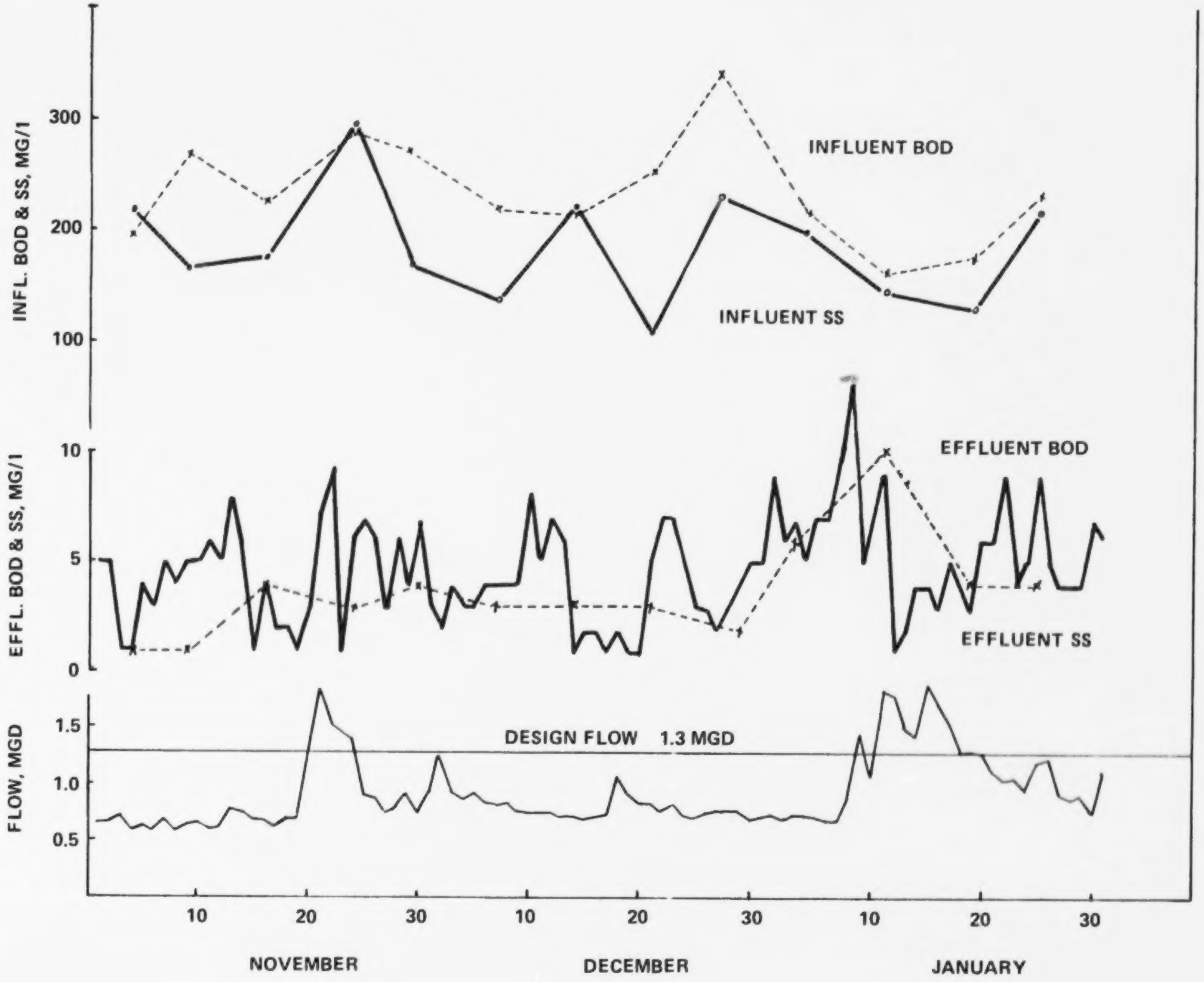


Fig. 8.12 Actual performance of an oxidation ditch

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.3H How is the DO in the oxidation ditch regulated?

8.3I What should be the velocity in the ditch?

8.3J What observations should be made daily to help indicate the performance of the oxidation ditch?

8.331 Abnormal Operation

In making the routine checks that are noted under Section 8.330, "Normal Operation, Records, Mechanical," you may occasionally find some conditions to be abnormal. Serious damage to the rotor assembly may result if the abnormal condition(s) are not corrected as soon as possible.

Rotor assembly operation is *ESSENTIAL* for the efficient operation of the oxidation ditch. Loss of rotor-generated mixing and air entrainment to the mixed liquor in the ditch for an extended period of time will turn your oxidation ditch activated sludge process into an upset, bulking activated sludge process.

Listed in Table 8.2 are some abnormal conditions, possible causes, and your response to the conditions that will aid you in the safe and efficient operation of the rotor.

Environmental factors that affect the wastewater treatment process include temperature and precipitation. The wastewater temperature affects the activity of the microorganisms. During cold weather this reduced activity might lower the efficiency of the treatment system. Besides biological effects of temperature, the flocculation and sedimentation of the mixed liquor solids is not as effective at lower temperatures.

Ice buildup will hinder or stop altogether the proper operation of mechanical parts such as rotors and sludge scraper mechanisms. Chunks of ice may develop that float in the ditch and eventually enter the area of the rotor assembly. Unless adequate safeguards are provided, serious damage to the rotor *WILL* result. Some of the safeguards that *MUST* be considered are:

1. The oxidation ditch in cold weather areas *SHOULD BE OPERATED FOR THE MAXIMUM DETENTION TIME PRACTICAL* in order to conserve as much heat in the wastewater as possible. This action will inhibit ice chunk formation.
2. The splashing and/or spraying action produced by the rotor will allow ice to form on the rotor assembly. Serious consideration must be given to covering the whole rotor assembly with a structure made of wood, fiberglass or other suitable material that will bridge over the ditch. Installations of this type generally are not heated.

   NOTE: If it is necessary to shut the rotor "OFF" for maintenance, *ICE WILL FORM ON THE ROTOR.* Prior to restarting the rotor, hose it off with water to thaw the ice. Otherwise the ice could cause vibrations that can damage the rotor.

   CAUTION: Ice conditions in winter require spiked shoes and sanding icy areas if the ice cannot be thawed away with wash water.

In some treatment plants, very heavy rains or snow melts cause flows to the treatment plant to exceed three to four times design flow. This is generally accompanied by a weaker wastewater in terms of BOD and COD due to the dilution effect of the stormwater. These hydraulic overloads may exceed the capacity of the clarifier to settle sludge solids properly. When this occurs, extremely high BOD, COD and suspended solids concentrations will be discharged to the receiving stream in the final effluent and possible process upsets can occur if corrective action is not taken. Chemicals such as alum, ferric chloride, and polymers can be added to the final settling tank to assist in settling solids during abnormal conditions. When chemicals such as alum are used, the volume of return sludge is increased and the pH of the sludge may be reduced.

Another method of preventing hydraulic overloads from causing this discharge of high BOD, COD and suspended solids concentrations is to shut down one or more rotor assemblies in the ditch. This will allow the ditch to act as a large settling tank, keeping the MLSS from flowing into the clarifier where they could be washed out. When the plant flow decreases to more normal levels, the rotor(s) can then be restarted to resume normal operation.

Other than the above corrective actions, without plant modifications there is not much the operator can do to offset the changes in treatment efficiency caused by temperature changes and high flows during abnormal conditions. However, ice buildup can be controlled by frequent observation and removal during cold periods. For persistent cold weather problems, construction of a *LIGHTWEIGHT* building over the ditch and clarifier may be more economical in the long run than fighting ice. The normal wastewater temperature will generally supply sufficient heat inside a building to prevent ice from forming.

Usually it is necessary to vary the amount of MLSS in the ditch as seasons change. Because the microorganisms are not as active in winter at low temperatures, the MLSS will need to be higher in the winter than in the summer if complete nitrification is desired.

8.332 Shutdown

Shutdown of the oxidation ditch may be necessary for emergency repairs. Try to schedule any shutdowns so the activated sludge microorganisms will be without air for the shortest possible time period. Problems such as odors and a loss of the microorganism culture can start within two hours after the rotors have been shut off. The microorganism culture may start to deteriorate within 10 minutes, but can recover quickly if the down time does not exceed four hours. If possible, try to keep one rotor operating at all times.

Shutdown of the rotor assembly is required when any maintenance function is performed to prevent injury to personnel.

a. Turn the "on-off" switch to "OFF."

b. Turn the main power breaker "OFF."

c. Lock-out and tag the main power breaker in the "OFF" position.

Maintenance work may now be performed.

If the oxidation ditch treats seasonal loads and is shut down during the off-season, protect equipment from the weather and moisture.

8.333 Troubleshooting

Refer to Section 8.252, "Troubleshooting." The problems of package aeration plants and the solutions are very similar to those of oxidation ditches.

If floatables appear in the final settling tank, examine the baffle around the level control weir. Since oxidation ditches do not have primary clarifiers, plastic goods and other floatables

TABLE 8.2 ABNORMAL BRUSH ROTOR OPERATION

ITEM	ABNORMAL CONDITION	POSSIBLE CAUSE	OPERATOR RESPONSE
Motor	Motor "off"	Ambient temperature in switchboard panel or room too high.	Reduce temperature with fans.
		Degree of rotor submergence results in excessive amperage draw.	Adjust rotor submergence.
		Motor shorted or burned out.	Check for overloading. Repair motor.
	Motor "hot" to the touch	Dry bearings.	Lubricate bearings
		Excessive grease.	Remove grease and grease properly.
		Worn bearings.	Replace bearings.
		Excessive amperage draw (motor load).	Adjust rotor submergence.
Gear Reducer	Grinding, chipping, whirring or whining noise	Low oil level.	Drain and/or refill. Check for leakage and make repairs.
		Gear drive part(s) partially or totally worn.	Replace worn parts.
Bearings	Grinding or bumping noise	Insufficient bearing grease.	Grease bearing(s) routinely.
		Worn bearing(s).	Replace bearing(s)

can be a problem if the baffle is not properly adjusted.

8.334 Operational Strategy

Refer to Section 8.254, "Operational Strategy." The items considered in the operational strategy for package aeration plants are the same as those considered for oxidation ditches.

8.34 Maintenance

8.340 Housekeeping

A general cleanup each day at the plant is important. This not only gives you a more pleasant place to work, but also helps your plant perform better.

Daily cleanup usually includes removing and burying of debris that may have accumulated on the bar screen; removal of grease and scum from the surface of the clarifier and washdown or brushing down the ditch and clarifier weirs and walls.

8.341 Equipment Maintenance

Regularly scheduled equipment maintenance must be performed. As boring as some equipment manufacturer's instructional books may be, *READ THEM*! Learn what they say. You should check each piece of equipment daily to see that it is functioning properly. You may have very few mechanical devices in your oxidation ditch plant, but they are all important. The rotors and pumps should be inspected to see that they are operating properly. If pumps are clogged, the obstructions should be removed. Listen for unusual noises. Check for loose bolts. Uncovering a mechanical problem in its early stages could prevent a costly repair or replacement at a later date.

Lubrication should also be performed with a fixed operating schedule and properly recorded. Follow the lubrication and maintenance instructions furnished with each piece of equipment. If you are unable to find the instructions, write to the manufacturer for a new set. Make sure that the proper lubricants are used. Over-lubrication is wasteful and reduces the effectiveness of lubricant seals and may cause overheating of bearings or gears.

Painting should be done periodically. In addition to beautifying your plant, it gives a good protective coating on all iron and/or metal surfaces and will prolong the life of the metal. *NEVER PAINT OVER* equipment identification tags! You will regret it if you do.

You should make it your business to know the manufacturer of every piece of equipment in your plant. Knowing the manufacturer and how to quickly contact the manufacturer may save important time and money when equipment breakdowns occur.

1. Motors (See Chapter 15, "Maintenance," for additional details.)

Motors should be greased after about 2,000 hours of operation or as often as conditions and/or the manufacturer recommends. The motor must be stopped when greasing begins.

Remove the filler and drain plugs, free the grease holes of any hardened grease, add new grease through the filler hole until it starts to come out of the drain hole. Start the motor and let it run for about 15 minutes to expel any excess grease. Stop the motor and install the filler and drain plugs.

Rotor assembly motors are generally very much exposed to a high degree of moisture. For this reason the motor should be checked at least yearly by an electrician to be sure all parts are in good, working condition.

2. Gear Reducer

Generally all new oil-lubricated equipment has a "break-in" period of about 400 hours. After this time the oil should be drained from the gear reducer, the unit flushed and new oil added. This procedure removes fine metal particles that have worn off the internal components as a result of the initial close tolerances as the equipment was "breaking-in." If large quantities of fine metal particles are found after the "break-in" period, the manufacturer should be consulted.

A high quality turbine-type oil is normally used in the gear reducer assembly. Frequency of oil change is after about 1,400 hours of operation under normal service conditions.

3. Bearings

   a. Gear Reducer Bearings

These bearings are generally greased twice per week *WHILE THE ROTOR ASSEMBLY IS IN OPERATION* to insure proper distribution of the lubricant.

Extension tubes or pipes are usually attached to the bearing cap. A grease fitting is then installed on the other end of the tube or pipe. This allows for safety when greasing the bearings while the rotor is operating by extending the grease fitting away from the hazardous area of the operating rotor. This grease fitting modification may be used in other equipment applications where lubrication of running equipment would present a safety hazard.

   b. Rotor Intermediate and Outboard Bearings

These bearings are generally lubricated *DAILY WHILE THE ROTOR ASSEMBLY IS IN OPERATION.*

In most bearing lubrication applications, over-lubrication is wasteful and reduces the effectiveness of lubricant seals and may cause overheating of bearings. Rotor intermediate and outboard bearings ARE GENERALLY THE EXCEPTION. As a rule, these bearings cannot be over-lubricated.

Some rotor bearings are protected by neoprene seals which retain lubricant and keep out moisture. The rotor shaft may have "slingers" near the bearing and a detachable shield may cover the bearing. Be sure you do not over-lubricate and destroy the seals.

4. Lubrication

Lubrication of this equipment in locations that have extreme weather variations is critical. Oil and grease must be changed with the proper type and grade, for the expected weather conditions, as determined by the equipment manufacturer.

NOTE: The proper type and grade of oil is a necessity. If it is too thin or too thick it will interfere with proper functioning of bearings and gears.

Bearing grease changes may be accomplished by flushing the grease housing with a 30 to 90 weight oil. The oil is added in the same manner as the grease.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 268.

8.3K What problems can be caused by ice during cold weather?

8.3L Why are more microorganisms (higher MLSS) needed in the ditch during cold weather than during warm weather?

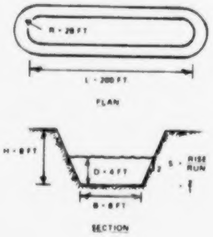
8.3M Why is a general cleanup each day at the plant important?

8.35 Operational Guidelines

8.350 English System

Section 8.301, "Description of Oxidation Ditches," lists operational guidelines for an oxidation ditch plant. This section outlines the procedures for you to follow to calculate the guidelines for your oxidation ditch. The first step is to draw a sketch of your oxidation ditch, to obtain the important dimensions, and to record the appropriate flow and wastewater characteristics.

1. Oxidation ditch dimensions
   a. Length, ft = 200 ft
   b. Bottom, ft = 8 ft
   c. Height, ft = 8 ft
   d. Depth, ft = 4 ft
   e. Radius, ft = 28 ft
   f. Slope = 2

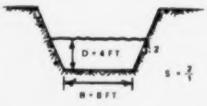


2. Flow and waste characteristics
   a. Flow, MGD, = 0.2 MGD
   b. BOD, mg/*L* = 200 mg/*L*
   c. Infl. SS, mg/*L* = 200 mg/*L*
   d. MLSS, mg/*L* = 4,000 mg/*L*
   e. Volatile Matter in MLSS = 70%

3. Calculate oxidation ditch volume in cubic feet and million gallons.
   a. Determine cross-sectional area.

   Find average width of water in ditch, W in feet.

$$\text{W, ft} = B + \frac{D}{S}$$
$$= 8\text{ ft} + \frac{4\text{ ft}}{2}$$
$$= 8\text{ ft} + 2\text{ ft}$$
$$= 10\text{ ft}$$



$$\text{Area, sq ft} = W\,D$$
$$= 10\text{ ft} \times 4\text{ ft}$$
$$= 40\text{ sq ft}$$

   b. Determine the center line length of the ditch. Find the length around the two ends.

$$\text{Ends, L, ft} = 2\,\pi\,R$$
$$= 2 \times 3.14 \times 28\text{ ft}$$
$$= 178\text{ ft}$$

$$\text{Total L, ft} = \text{Ends L, ft} + 2\text{ L, ft}$$
$$= 178\text{ ft} + 2 \times 200\text{ ft}$$
$$= 578\text{ ft}$$

   c. Calculate ditch volume.

$$\text{Vol, cu ft} = \text{Length, ft} \times \text{Area, sq ft}$$
$$= 578\text{ ft} \times 40\text{ sq ft}$$
$$= 23{,}120\text{ cu ft}$$
$$= 23.12\ \ (1{,}000\text{ cu ft})\text{(read as 23.12 one thousand cubic feet)}$$

$$\text{Vol, gal} = 23{,}120\text{ cu ft} \times 7.48\text{ gal/cu ft}$$
$$= 172{,}940\text{ gal}$$
$$= 0.173\text{ MG}$$

4. Calculate the BOD loading in pounds BOD per day and pounds BOD per day per 1000 cu ft of ditch volume.

$$\text{BOD Loading, lbs/day} = \text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34\text{ lbs/gal}$$
$$= 0.2\text{ MGD} \times 200\text{ mg}/L \times 8.34\text{ lbs/gal}^{*}$$
$$= 334\text{ lbs BOD/day}$$

$$\text{BOD Loading, lbs/day/1,000 cu ft} = \frac{\text{BOD, lbs/day}}{\text{Ditch Vol., 1,000 cu ft}}$$
$$= \frac{334\text{ lbs/day}}{23.12\text{ - }(1{,}000\text{ cu ft})}$$
$$= 14\text{ lbs BOD/day/1,000 cu ft}$$

5. Determine the Food/Microorganism Ratio
   a. Microorganisms are measured as pounds of Mixed Liquor Volatile Suspended Solids under aeration in the oxidation ditch. VM means Volatile Matter.

$$\text{MLVSS, lbs} = \text{Vol., MG} \times \text{MLSS, mg}/L \times \text{VM} \times 8.34\text{ lbs/gal}$$
$$= 0.173\text{ MG} \times 4{,}000\text{ mg}/L \times 0.70 \times 8.34\text{ lbs/gal}$$
$$= 4{,}040\text{ lbs}$$

   b. Calculate F/M Ratio

$$\frac{F}{M} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$
$$= \frac{334\text{ lbs BOD/day}}{4{,}040\text{ lbs MLVSS}}$$
$$= 0.08\text{ lbs BOD/day/lb MLVSS}$$

6. Determine the Sludge Age, days.
   a. Calculate pounds of solids under aeration

$$\text{Aeration Solids, lbs} = \text{Vol., MG} \times \text{MLSS, mg}/L \times 8.34\text{ lbs/gal}$$
$$= 0.173\text{ MG} \times 4{,}000\text{ mg}/L \times 8.34\text{ lbs/gal}$$
$$= 5{,}770\text{ lbs}$$

   b. Calculate solids fed to ditch, lbs/day

$$\text{Solids Added, lbs/day} = \text{Flow, MGD} \times \text{Infl. SS, mg}/L \times 8.34\text{ lbs/gal}$$
$$= 0.2\text{ MGD} \times 200\text{ mg}/L \times 8.34\text{ lbs/gal}$$
$$= 334\text{ lbs/day}$$

---

* Remember that 1 liter = 1,000,000 mg and that

$$\frac{\text{lbs}}{\text{day}} = \frac{\text{Mil. Gal}}{\text{day}} \times \frac{\text{mg}}{\text{Mil. mg}} \times \frac{\text{lbs}}{\text{gal}} = \frac{\text{lbs}}{\text{day}}$$

c. Calculate Sludge Age, days

$$\text{Sludge Age, Days} = \frac{\text{Solids Under Aeration, lbs}}{\text{Solids Added, lbs/day}}$$

$$= \frac{5{,}770 \text{ lbs}}{334 \text{ lbs/day}}$$

$$= 17 \text{ days}$$

7. Calculate ditch detention time, hours.

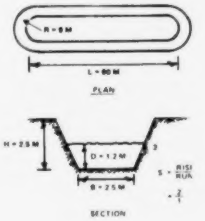
$$\text{Detention Time, hours} = \frac{\text{Ditch Volume, MG} \times 24 \text{ hr/day}}{\text{Flow, MGD}}$$

$$= \frac{0.173 \text{ MG} \times 24 \text{ hr/day}}{0.2 \text{ MGD}}$$

$$= 20.8 \text{ hours}$$

8.351 Metric System

This section will show you how to calculate operational criteria using the metric system. To start you must collect the same basic information.



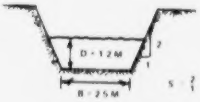
1. Oxidation ditch dimensions.
   a. Length, m = 60 meters
   b. Bottom, m = 2.5 meters
   c. Height, m = 2.5 meters
   d. Depth, m = 1.2 meters
   e. Radius, m = 9 meters
   f. Slope = 2
2. Flow and waste characteristics.
   a. Flow, cu m/day = 750 cu m/day
   b. BOD, mg/*L* = 200 mg/*L*
   c. Infl., SS, mg/*L* = 200 mg/*L*
   d. MLSS, mg/*L* = 4,000 mg/*L*
   e. Volatile Matter in MLSS = 70%
3. Calculate oxidation ditch volume in cubic meters.
   a. Determine cross-sectional area.

   Find average width of water in ditch, w in meters.

$$\text{W, m} = \text{B} + \frac{\text{D}}{\text{S}}$$

$$= 2.5 \text{ m} + \frac{1.2 \text{ m}}{2}$$

$$= 3.1 \text{ m}$$



$$\text{Area, sq m} = \text{W D}$$

$$= 3.1 \text{ m} \times 1.2 \text{ m}$$

$$= 3.72 \text{ sq m}$$

   b. Determine the center length of the ditch. Find the length around the two ends.

$$\text{Ends L, m} = 2\,\pi\,\text{R}$$

$$= 2 \times 3.14 \times 9 \text{ m}$$

$$= 56.5 \text{ m}$$

$$\text{Total L, m} = \text{Ends L, m} + 2 \text{ L, m}$$

$$56.5 \text{ m} + 2 \times 60 \text{ m}$$

$$= 176.5 \text{ m}$$

   c. Calculate ditch volume.

$$\text{Vol, cu m} = \text{Length, m} \times \text{Area, sq m}$$

$$= 176.5 \text{ m} \times 8.72 \text{ sq m}$$

$$= 657 \text{ cu m}$$

$$= 0.657 \text{ -(1,000 cu m)(read as one thousand cubic meters)}$$

4. Calculate the BOD loading in kg BOD per day and kg BOD per day per 1,000 cu m of ditch volume.

$$\text{BOD Loading, kg/day} = \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \text{BOD, } \frac{\text{mg}}{L} \times \frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}} \times \frac{1000\ L}{1 \text{ cu m}}$$

$$= 750\ \frac{\text{cu m}}{\text{day}} \times 200\ \frac{\text{mg}}{L} \times \frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}} \times \frac{1000\ L}{1 \text{ cu m}}$$

$$= 150 \text{ kg BOD/day}$$

$$\text{BOD Loading kg/day/1,000 cu m} = \frac{\text{BOD, kg/day}}{\text{Ditch Volume, 1,000 cu m}}$$

$$= \frac{150 \text{ kg/day}}{0.657 \text{ - (1,000 cu m)}}$$

$$= 228 \text{ kg BOD/day/1,000 cu m}$$

5. Determine the Food/Microorganism Ratio.
   a. Calculate kilograms of MLVSS under aeration in the oxidation ditch

$$\text{MLVSS, kg} = \text{Vol, cu m} \times \text{MLSS, } \frac{\text{mg}}{L} \times \text{VM} \times \frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}} \times \frac{1{,}000\ L}{1 \text{ cu m}}$$

$$= 657 \text{ cu m} \times 4{,}000\ \frac{\text{mg}}{L} \times 0.70 \times \frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}} \times \frac{1{,}000\ L}{1 \text{ cu m}}$$

$$= 1,\ 840 \text{ kg}$$

   b. Calculate F/M Ratio

$$\frac{\text{F}}{\text{M}} = \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

$$= \frac{150 \text{ kg BOD/day}}{1{,}840 \text{ kg MLVSS}}$$

$$= 0.08 \text{ kg BOD/day/kg MLVSS}$$

6. Determine the Sludge Age, days.
   a. Calculate kilogram of solids under aeration

$$\text{Aeration Solids, kg} = \text{Vol, cu m} \times \text{MLSS, mg/}L \times \frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}} \times \frac{1{,}000\ L}{1 \text{ cu m}}$$

$$= 657 \text{ cu m} \times 4{,}000 \text{ mg/}L \times \frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}} \times \frac{1{,}000\ L}{1 \text{ cu m}}$$

$$= 2{,}628 \text{ kg}$$

b. Calculate solids fed to ditch, kg/day

$$\begin{aligned}\text{Solids Added, kg/day} &= \text{Flow, cu m/day} \times \text{Infl. SS, mg/}L \times \frac{1\text{ kg}}{1{,}000{,}000\text{ mg}} \times \frac{1{,}000\ L}{1\text{ cu m}}\\ &= 750\text{ cu m/day} \times 200\text{ mg/}L \times \frac{1\text{ kg}}{1{,}000{,}000\text{ mg}} \times \frac{1{,}000\ L}{1\text{ cu m}}\\ &= 150\text{ kg/day}\end{aligned}$$

c. Calculate Sludge Age, days

$$\begin{aligned}\text{Sludge Age, Days} &= \frac{\text{Solids Under Aeration, kg}}{\text{Solids Added, kg/day}}\\ &= \frac{2{,}628\text{ kgs}}{150\text{ kg/day}}\\ &= 17.5\text{ days}\end{aligned}$$

7. Calculate ditch detention time, hours.

$$\begin{aligned}\text{Detention Time, hours} &= \frac{\text{Ditch Volume, cu m} \times 24\text{ hr/day}}{\text{Flow, cu m/day}}\\ &= \frac{657\text{ cu m} \times 24\text{ hr/day}}{750\text{ cu m/day}}\\ &= 21\text{ hours}\end{aligned}$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 269.

8.3N Determine the BOD loading on an oxidation ditch in:

1. Pounds of BOD/day; and
2. Kilograms of BOD/day.

The inflow is 0.8 MGD and the influent BOD is 250 mg/*L*.

1 MGD = 3,785 cu m/day

8.4 REVIEW OF PLANS AND SPECIFICATIONS

As an operator you can be very helpful to design engineers in pointing out some design features that would make your job easier. This section indicates some of the items that you should look for when reviewing plans and specifications for expansion of existing or construction of new package plants and oxidation ditches.

8.40 Package Plants

1. Is the plant designed for implementation of modifications to the activated sludge process (adequate flexibility to accommodate future treatment requirements)?
2. Are adequate standby units (equipment) designed into the system?
3. Are ladders and walkways provided to allow easy access to equipment, pipes, and valves for normal operation, routine maintenance or repair?
4. Are adequate remote and local controls provided for the mechanical equipment?
5. Is the equipment and related instrumentation designed to operate at low flows and loads common in the early stages of plant operation?
6. Are adequate dewatering systems provided to permit rapid servicing of submerged equipment?
7. Is the chlorination facility flexible enough to allow for prechlorination or return activated sludge chlorination and are adequate control devices provided?
8. Is the treatment plant's total connected horsepower adequate to allow operation of all equipment in parallel?
9. Are flow equalization facilities provided to handle high flows during wet weather or industrial discharges?
10. Is adequate support equipment provided to allow easy and safe removal of aeration diffusers?
11. Is a laboratory provided with appropriate equipment for conducting at least minimum process control tests?
12. Are adequate sludge drying beds provided with consideration given to wet weather conditions?
13. Is a sludge transfer pump provided to transfer sludge to the drying beds?
14. Are the beds designed for easy removal of dried sludge and are there provisions for proper disposal of the sludge?
15. Is there a provision for waste or digested sludge liquid storage in lieu of or addition to sludge drying beds?
16. Is standby or auxiliary power provided?

8.41 Oxidation Ditches

1. Influent and return activated sludge fed to aeration reactor should be located just upstream of a rotor assembly to afford immediate mixing with mixed liquor in the channel.
2. Effluent from the aeration channel should be upstream of the rotor and far enough upstream from the injection of the influent and return activated sludge to prevent short-circuiting.
3. Water level in the aeration channel should be controlled by an adjustable weir. In calculating weir length, use maximum raw flow plus maximum recirculated flow to prevent excessive rotor immersions.
4. Walkways must be provided across the aeration channel to provide access to the rotor for maintenance. The normal location is upstream of the rotor. Location should be such to prevent spray from the rotor on the walkway.
5. Horizontal baffles, placed within 15 feet (4.5 m) downstream of the rotor should be used on all basins with water depths over 6 feet (1.8 m) to provide proper mixing of the entire depth of the basin.
6. In a single oxidation ditch or aeration channel, the rotor drive assembly should be on the outboard side for ease of access.
7. The ditch should be constructed with some type of lining. Consideration should be given to the most economical means of lining available in the particular plant location. As typical liners, consideration could be given to gunite or shotcrete, poured concrete or earthen walls, asphalt, or precast concrete or tile.
8. All drive and gear assemblies should be elevated out of the water and safe and easy access should be provided for maintenance.
9. Standby or auxiliary power must be provided to operate critical equipment.

10. Floating aerators and related equipment should be provided in case of rotor failure in order to maintain adequate treatment.

11. Secondary clarifier.

    a. Surface Rate: 600 gal/day/sq ft (24 cu m/day/sq m) based upon plant design flow. Where wide variations in plant hydraulic loading are expected, care should be taken to limit maximum instantaneous surface rate to 1200 gal/day/sq ft (49 cu m/day/sq m).

    b. Solids Loading: Normal oxidation ditch operation and surface rates will prevent excessive solids loading to the final clarifier. However, if complete nitrification is required 12 months per year, the maximum instantaneous solids loading must not exceed 45 lbs/day/sq ft (200 kg/day/sq m).

    c. Detention Time: Three hours based on plant design flow. In no case however should the final clarifier have a side water depth less than eight feet (2.4 m).

12. Effluent disposal.

    a. Receiving Stream: The discharge pipe should be located where flood water will not flow back into the plant if there is a power outage or pump failure. Be sure the outlet in the receiving waters is submerged to reduce foam and scum problems.

    b. Percolation Ditch: Design should be based on a percolation rate of gallons per lineal foot of ditch. Provisions must be made to prevent blowing sand and/or dirt from entering the ditch.

13. Winter climates.

    a. Provisions should be made to maximize detention times in order to conserve as much heat as possible in the wastewater.

    b. Is it practical to cover the oxidation ditch? If not, consider a large and a small ditch or a single ditch that can be modified to use only half its total capacity.

    c. Be sure that all equipment requiring normal maintenance be housed and/or heated. This will extend the useful life of the equipment and facilitates service work. Changing a gear box, repairing a pipe, or installing electrical components becomes a major task at very low temperatures.

    d. The rotor assembly should be provided with a lightweight cover to prevent rotor icing.

    e. Equip the clarifier with a light-weight tarpaulin to keep heavy snow out of the clarifier and to reduce freezing problems.

    f. A subsurface disposal pipeline and percolation field should be provided for effluent disposal in winter months. A percolation ditch will freeze over in the winter.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 269.

8.4A What provisions should be made to permit rapid servicing of submerged equipment?

8.4B What items would you check when reviewing the location of a walkway intended to provide access to the rotor for maintenance?

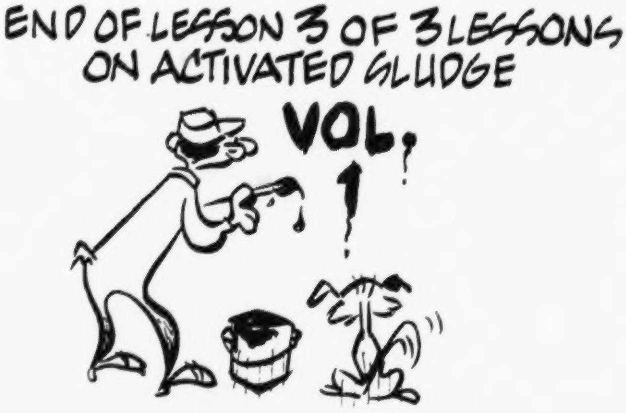
8.5 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read all of Section A.8, Pumps. Also work the example problems and check the arithmetic using your calculator.

In Section A.13, Typical Wastewater Treatment Plant Problems, read and work the problems in Section A.135, Activated Sludge.

8.5 METRIC CALCULATIONS

Refer to Section 8.35, "Operational Guidelines," for metric calculations.


END OF LESSON 3 OF 3 LESSONS
ON ACTIVATED SLUDGE
VOL. 1

Please answer the discussion and review questions before working the Objective Test.

DISCUSSION AND REVIEW QUESTIONS

(Lesson 3 of 3 Lessons)

Chapter 8. ACTIVATED SLUDGE

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

11. What happens to inorganic solids such as grit, sand and silt that enter an oxidation ditch plant?
12. During plant start-up, what does a dark grey color in the mixed liquor indicate and what would you do if this condition persists for more than several days?
13. During plant start-up, when should water be discharged to the clarifier?
14. How can an operator determine if the sludge wasting rate should be increased or decreased?
15. What would you do if solids were in the effluent of the final settling tank during high flows caused by storms or during high influent solids levels caused by the cleaning of the collection system sewers?

Please work the objective test next.

SUGGESTED ANSWERS

Chapter 8. ACTIVATED SLUDGE

Answers to questions on page 240.

8.0A The purpose of the activated sludge process in treating wastewater is to oxidize and remove soluble or finely divided suspended materials that were not removed by previous treatment.

8.0B A stablized waste is a waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

8.0C Air is added to the aeration tank in the activated sludge process to provide oxygen to sustain the living organisms and for oxidation of wastes to obtain energy for growth. The application of air also encourages mixing in the aerator.

8.0D Air requirements increase when the strength (BOD) of the incoming wastes increases because more food (wastes) encourages biological activity (reproduction and respiration).

8.0E Factors that could cause an unsuitable environment for the activated sludge process in an aeration tank include:

1. High concentrations of acids, bases, and other toxic substances.
2. Uneven flows of wastewater that cause overfeeding or starvation.
3. Failure to supply enough oxygen.

Answers to questions on page 240.

8.1A Effluent quality requirements may be stated by regulatory agencies in terms of percentage removal of wastes or allowable quantities of wastes that may be discharged.

8.1B Harmful industrial waste discharges may be regulated by preventing discharge to the collection system, requiring pretreatment, or controlling the discharge in order to protect an activated sludge process.

END OF ANSWERS TO QUESTIONS IN LESSON
1

Answers to questions on page 245.

8.2A A typical package extended aeration plant may have either two or three compartments. The purpose of each compartment is:

1. Aeration. Aerate and mix waste to be treated with activated sludge.
2. Clarification and Settling. Allow activated sludge to be separated from water being treated. Clarified effluent leaves plant and settled activated sludge is returned to aeration tank to treat more wastewater.
3. Aerobic digestion (optional). Treatment of waste activated sludge.

8.2B Common characteristics of all package aeration plants include long solids retention times, high mixed liquor suspended solids and low food/microorganism ratios.

Answers to questions on page 248.

8.2C Package plants should have cathodic protection to prevent rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.

8.2D The valve to the air lift pumps must be closed until the settling compartment is filled or all of the air will attempt to flow out the air lifts and no air will flow out the diffusers.

8.2E If the water in the aeration compartment was murky or cloudy and the aeration compartment had a rotten egg odor (H_2S), you should increase the aeration rate.

Answers to questions on page 250.

8.2F A package plant should be visually checked by an operator every day.

8.2G For best results, in terms of effluent quality, waste about five percent of the solids each week during warm weather operation.

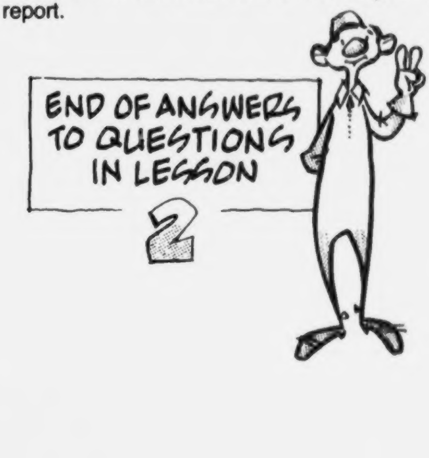
8.2H a. If the solids do not settle in the jar, the aeration rate should be increased.

b. If the solids settle and then float to the surface, the aeration rate should be reduced a little each day until the solids settle properly.

Answers to questions on page 251.

8.2I Operators can avoid being injured on the job by avoiding hazardous conditions and using safe procedures.

8.2J If you must work alone, phone your office at regular intervals and have someone check on you if you fail to report.


END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 255.

8.3A The major components of an oxidation ditch treatment process include:

1. Oxidation ditch,
2. Rotor,
3. Level control weir,
4. Final settling tank,
5. Return sludge pump, and
6. Excess sludge handling facilities.

8.3B The ends of oxidation ditches are well rounded to prevent eddying and dead areas.

8.3C Operators should avoid walking on top of oxidation ditch sidewalls to avoid slipping and falling into the ditch.

Answers to questions on page 257.

8.3D The two primary objectives of start-up are to:

1. Make certain that all mechanical equipment is operating properly; and
2. Develop a proper microbial floc (activated sludge) in the oxidation ditch.

8.3E The following items or structures should be inspected during the pre-start inspection.

1. Inlet structure,
2. Oxidation ditch structure,
3. Rotor,
4. Adjustable weir,
5. Clarifier structure and piping, and
6. Return sludge and waste sludge systems.

8.3F During plant start up, start the rotors when the water level in the ditch reaches the bottom of the rotors.

8.3G When an oxidation ditch is operating properly, the solids should look like particles, golden to rich dark brown in color, with sharply defined edges.

Answers to questions on page 260.

8.3H The DO in the oxidation ditch is regulated by raising or lowering the ditch outlet level control weir. This weir controls the level of water in the ditch which in turn regulates the degree of submergence of the rotors. The greater the submergence, the more oxygen is transferred from the air.

8.3I The ditch velocity should be maintained between 1.0 and 1.5 fps (0.3 to 0.45 mps).

8.3J Daily observations of ditch color, odors, lack of foam on the aerator surface and settling tank clarity help indicate the performance of the oxidation ditch.

Answers to questions on page 262.

8.3K During cold weather ice buildup will hinder or stop altogether the proper operation of mechanical parts such as rotors and sludge scraper mechanisms.

8.3L More microorganisms are needed to treat the same amount of wastes during cold weather than during warm weather because the colder the water, the less active the microorganisms.

8.3M A general cleanup each day provides a more pleasant place to work and also improves plant performance.

Answers to questions on page 265.

8.3N

Known	Unknown
Flow, MGD = 0.8 MGD	1. BOD Loading, lbs/day
BOD, mg/*L* = 250 mg/*L*	2. BOD Loading, kg/day
1 MGD = 3,785 cu m/day	

1. Determine BOD loading, lbs/day.

$$\text{BOD Loading, lbs/day} = \text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34\ \text{lbs/gal}$$

$$= 0.8\ \text{MGD} \times 250\ \text{mg}/L \times 8.34\ \text{lbs/gal}$$

$$= 1{,}668\ \text{lbs BOD/day}$$

2. Determine BOD Loading, kg/day.

a. Convert flow from MGD to cubic meters per day.

$$\text{Flow, cu m/day} = \text{Flow, MGD} \times \frac{3785\ \text{cu m/day}}{1\ \text{MGD}}$$

$$= \frac{0.8\ \text{MGD} \times 3785\ \text{cu m/day}}{1\ \text{MGD}}$$

$$= 3028\ \text{cu m/day}$$

b. Calculate BOD loading, kg/day

$$\text{BOD Loading, kg/day} = \text{Flow, cu m/day} \times \text{BOD, mg}/L \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}} \times \frac{1{,}000\ L}{1\ \text{cu m}}$$

$$= 3028\ \text{cu m/day} \times 250\ \text{mg}/L \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}} \times \frac{1{,}000\ L}{1\ \text{cu m}}$$

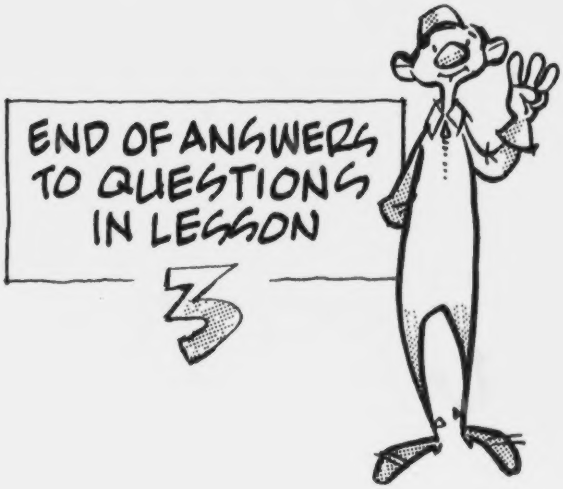
$$= 757\ \text{kg BOD/day}$$

Answers to questions on page 266.

8.4A Adequate dewatering systems should be provided to permit rapid servicing of submerged equipment.

8.4B When reviewing the location of a walkway intended to provide access to the rotor for maintenance, check:

1. Distance from walkway to rotor,
2. Normal location is upstream from rotor, and
3. Spray from the rotor will not fall on the walkway.


END OF ANSWERS TO QUESTIONS IN LESSON
3

OBJECTIVE TEST

Chapter 8. ACTIVATED SLUDGE

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

QUESTIONS 1 THROUGH 8 ARE MATCHING

DIRECTIONS: Match the word with the correct definition by marking the number of the definition on the answer sheet opposite the number of the word.

EXAMPLE

QUESTIONS

Word	Definition
1. Plant Operator	1. Advocate of higher taxes
2. Plant Superintendent	2. Hard-working water quality protector
	3. Manager of athletic program
	4. Person in charge of a treatment plant
	5. Uneducated individual

ANSWER SHEET

	1	2	3	4	5
1.		▨			
2.				▨	

MATCHING

Word	Definition
1. Aliquot	1. Airline schedule
2. Coning	2. Bacteria that have come together and formed a cluster
3. Flights	3. Caused by sludge when removed too quickly
4. Floc	4. Portion of a sample
	5. Scraper boards used to remove settled sludge to collection hoppers
5. Meniscus	1. A group of microscopic animals found in treatment processes
6. Orifice	2. A thin plate with a hole in the middle used to measure flow
7. Protozoa	3. Jelly-like substances of bacteria
8. Zoogleal Mass	4. Membranes in the membrane filter
	5. The curved top of a column of liquid in a tube

True-False

9. An activated sludge process is similar to a clarifier process.
   1. True
   2. False

10. Activated sludge contains bacteria, protozoa and rotifers.
    1. True
    2. False

11. Secondary clarifiers receive aeration tank effluent.
    1. True
    2. False

12. Secondary clarifier effluent goes directly to receiving waters.
    1. True
    2. False

13. Oxygen is necessary for growth of inorganic activated sludge.
    1. True
    2. False

14. The operation of a package aeration plant is similar to the operation of other activated sludge plants.
    1. True
    2. False

15. Good treatment of wastewater rarely results from interrupted operation of aeration equipment and should not be attempted.
    1. True
    2. False

16. A white, fluffy foam indicates low solids content in the aerator, while a brown, leathery foam suggests high solids concentrations.
    1. True
    2. False

17. Testing of solids condition in an aeration tank may be accomplished by the settling test.
    1. True
    2. False

18. In the settling test, if the solids settle to the bottom of the jar with a clear liquor on top and the solids stay down one hour and come up in two hours, this is an indication of poor operation.
    1. True
    2. False

19. Operators of wastewater treatment plants have a very good safety record.
    1. True
    2. False

20. A package activated sludge plant does not need a clarifier.
    1. True
    2. False

21. The level control weir measures the flow into the oxidation ditch.
    1. True
    2. False

22. Building up the MLSS concentration is the most important activity during the start-up process in a package activated sludge plant.
    1. True
    2. False

23. In very cold winter climates the rotor should not be stopped because ice will form on the rotor assembly.
    1. True
    2. False

Multiple Choice

24. Where does the term "activated" come from in the *ACTIVATED* sludge process?
    1. Activated air is used in the process.
    2. Activated carbon is used in the process.
    3. The microorganisms must be activated before they start treating the wastewater.
    4. The plant must be activated before the wastewater is treated.
    5. The sludge particles are teeming with bacteria, fungi, and protozoa.

25. Which of the following factors could cause a demand for more oxygen (increase in aeration rates) in an aeration tank?
    1. Increase in food (BOD) in aeration tank influent.
    2. Increase in inert or inorganic wastes.
    3. Increase in microorganisms.
    4. Increase in pH.
    5. Increase in toxic substances.

26. Before a package plant is started and before wastewater is allowed to enter the aeration tank, which of the following items should be checked?
    1. Chips in the coating on a steel tank.
    2. Influent gate or valve for proper operation.
    3. Provisions for corrosion control of steel tanks.
    4. Sludge age.
    5. Tank level from one end to other.

27. A package aeration plant with the potential of odor complaints from nearby homes can handle waste activated sludge by
    1. Applying sludge directly to drying beds.
    2. Discharging waste activated sludge into a vacuum filter.
    3. Disposing of waste activated sludge in an incinerator.
    4. Having septic tank pumper remove waste activated sludge.
    5. Pumping waste activated sludge to aerated holding tank for disposal in a sanitary landfill.

28. Package plants usually
    1. Have an extensive lab testing program.
    2. Have an operator at the plant 24 hours a day.
    3. Operate as extended aeration plants.
    4. Operate the aeration device continuously.
    5. Waste about five percent of the solids each week during summer operation.

29. Solids in the effluent from a package aeration plant could be caused by
    1. A strong stale septic influent.
    2. Either too high or too low a return sludge rate.
    3. Either too high or too low an aeration rate.
    4. Excessive plant inflows.
    5. Something toxic in the influent.

30. Odors from a package plant could be caused by
    1. Aeration rates being too low.
    2. Excessive aeration rates.
    3. Improper disposal of waste activated sludge.
    4. Plugged sludge return line.
    5. Poor housekeeping.

31. Major components of an oxidation ditch wastewater treatment plant include.
    1. Bar screen.
    2. Final settling tank.
    3. Grit channel.
    4. Primary clarifier.
    5. Rotors.

32. A pre-start inspection of an oxidation ditch structure should include which of the following items?
    1. Cleanliness of diffusers.
    2. Making sure flights or scrapers move freely.
    3. Operation of adjustable weir.
    4. Proper direction of rotor rotation.
    5. Removal of all debris from ditch.

33. Oxidation ditch solids (MLSS) concentrations are controlled by regulating
    1. Aeration rates.
    2. Operation of ditch skimmers.
    3. Operation of ditch sludge scrapers.
    4. Return sludge rates.
    5. Waste sludge rates.

34. Environmental factors that significantly affect an oxidation ditch treatment process include
    1. Air pollution.
    2. Ice.
    3. Precipitation and runoff.
    4. Temperature.
    5. Wind.

35. Regular daily maintenance of oxidation ditches includes
    1. Removing and burying debris from bar screen.
    2. Removal of grease and scum from surface of final settling tank.
    3. Removal of grit from bottom of ditch.
    4. Replacing rotor blades.
    5. Washing down and/or brushing down of ditch and clarifier walls.

END OF OBJECTIVE TEST

CHAPTER 9

WASTE TREATMENT PONDS

by

A. Hiatt

TABLE OF CONTENTS

Chapter 9. Waste Treatment Ponds

Page

OBJECTIVES 276

GLOSSARY 277

LESSON 1

9.1 Use of Ponds 279
9.2 History of Ponds in Waste Treatment 279
9.3 Pond Classifications and Applications 282
9.4 Explanation of Treatment Process 284
9.5 Pond Performance 286

LESSON 2

9.6 Starting the Pond 287
9.7 Daily Operation and Maintenance 288
- 9.70 Scum Control 288
- 9.71 Odor Control 288
- 9.72 Weed and Insect Control 288
- 9.73 Levee Maintenance 290
- 9.74 Headworks and Screening 290
- 9.75 Some Operating Hints 290
- 9.76 Abnormal Operation 291
- 9.77 Batch Operation 291
- 9.78 Shutting Down a Pond 291
- 9.79 Operating Strategy 291

9.8 Surface Aerators 292
9.9 Sampling and Analysis 295
- 9.90 Importance 295
- 9.91 Frequency and Location of Lab Samples 296
- 9.92 Expected Treatment Efficiencies 296
- 9.93 Response to Poor Pond Performance 298

9.10 Safety 298

LESSON 3

9.11 Review of Plans and Specifications 299
  9.110 Location 299
  9.111 Chemistry of Waste 299
  9.112 Headworks and Screening 299
  9.113 Flow-Measuring Devices 299
  9.114 Inlet and Outlet Structures 300
  9.115 Levees 300
  9.116 Pond Depths 300
  9.117 Fencing and Signs 305
  9.118 Surface Aerators 305
  9.119 Pond Loading (English and Metric Calculations) 305
9.12 Eliminating Algae from Pond Effluents 308
9.13 Arithmetic Assignment 309
9.14 Acknowledgment 309
9.15 Additional Reading 309
9.16 Metric Calculations 309
9.17 Pond Attachment 311

OBJECTIVES

Chapter 9. WASTE TREATMENT PONDS

Following completion of Chapter 9, you should be able to do the following:

1. Explain how waste treatment ponds work and what factors influence and control pond treatment processes,
2. Place a new pond into operation,
3. Schedule and conduct normal and abnormal operational and maintenance duties,
4. Collect samples, interpret lab results, and make appropriate adjustments in pond operation,
5. Recognize factors that indicate a pond is not performing properly, identify the source of the problem, and take corrective action,
6. Develop a pond operating strategy,
7. Conduct your duties in a safe fashion,
8. Determine pond loadings,
9. Identify the different types of ponds,
10. Keep records for a waste treatment pond facility, and
11. Review plans and specifications for new ponds.

GLOSSARY

Chapter 9. WASTE TREATMENT PONDS

ADVANCED WASTE TREATMENT   ADVANCED WASTE TREATMENT

Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes.

ALGAE (AL-gee)   ALGAE

Microscopic plants which contain chlorophyll and float or are suspended and live in water. They also may be attached to structures, rocks or other similar substances.

BIOFLOCCULATION (BUY-o-flock-u-LAY-shun)   BIOFLOCCULATION

The clumping together of fine, dispersed organic particles by the action of bacteria and algae. This results in faster and more complete settling of the organic solids in wastewater.

CHEMICAL OXYGEN DEMAND or COD   CHEMICAL OXYGEN DEMAND or COD

A measure of the oxygen-consuming capacity of inorganic and organic matter present in wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/*L* during a specific test. Results are not necessarily related to the biochemical oxygen demand because the chemical oxidant may react with substances that bacteria do not stabilize.

COMPOSITE (PROPORTIONAL) SAMPLE   COMPOSITE (PROPORTIONAL) SAMPLE
(com-POZ-it)

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

FACULTATIVE POND (FACK-ul-tay-tive)   FACULTATIVE POND

The most common type of pond in current use. The upper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.

FREE OXYGEN   FREE OXYGEN

Molecular oxygen available for respiration by organisms. Molecular oxygen is the oxygen molecule, O_2, that is not combined with another element to form a compound.

GRAB SAMPLE   GRAB SAMPLE

A single sample taken at neither a set time nor flow.

MEDIAN   MEDIAN

The middle measurement or value. When several measurements are ranked by magnitude (largest to smallest), half of the measurements will be larger and half will be smaller.

MOLECULAR OXYGEN   MOLECULAR OXYGEN

The oxygen molecule, O_2, that is not combined with another element to form a compound.

PARALLEL OPERATION   PARALLEL OPERATION

When wastewater being treated is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit. Also see SERIES OPERATION.

PERCOLATION (PURR-ko-LAY-shun)   PERCOLATION

The movement or flow of water through soil or rocks.

pH pH

pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.

$$\text{pH} = \text{Log}\,\frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is most acid, 14 is most basic, and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

PHOTOSYNTHESIS (foto-SIN-the-sis) PHOTOSYNTHESIS

A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. Land plants grow by the same process.

POPULATION EQUIVALENT POPULATION EQUIVALENT

A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pounds of oxygen per day for each person using the system (as measured by the standard BOD test).

$$\text{Pop. Equiv., persons} = \frac{\text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34\ \text{lbs/gal}}{0.2\ \text{lbs BOD/day/person}}$$

RIPRAP RIPRAP

Broken stones, boulders, or other materials placed compactly or irregularly on levees or dikes for the protection of earth surfaces against the erosive action of waves.

SERIES OPERATION SERIES OPERATION

When wastewater being treated flows through one treatment unit and then flows through another similar treatment unit. Also see PARALLEL OPERATION.

SPLASH PAD SPLASH PAD

A structure made of concrete or other durable material to protect bare soil from erosion by splashing or falling water.

STABILIZED WASTE STABILIZED WASTE

A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

STOP LOG STOP LOG

A log or board in an outlet box or device used to control the water level in ponds.

TERTIARY TREATMENT (TER-she-AIR-ee) TERTIARY TREATMENT

Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration. Also called ADVANCED WASTE TREATMENT.

TOXIC (TOX-ick) TOXIC

Poisonous.

TOXICITY (tox-IS-it-tee) TOXICITY

A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

CHAPTER 9. WASTE TREATMENT PONDS

USED FOR TREATMENT OF WASTEWATER AND OTHER WASTES

(Lesson 1 of 3 Lessons)

9.1 USE OF PONDS

Shallow ponds (three- to five-feet or 1 to 1.5 meters deep) are often used to treat wastewater and other wastes instead of, or in addition to, conventional waste treatment processes. (See Figs. 9.1 and 9.2 for typical plant layouts and Table 9.1 for purpose of pond parts.) When discharged into ponds, wastes are treated or *STABILIZED*[1] by several natural processes acting at the same time. Heavy solids settle to the bottom where they are decomposed by bacteria. Lighter suspended material is broken down by bacteria in suspension. Some wastewater is disposed of by evaporation from the pond surface.

TABLE 9.1 PURPOSE OF POND PARTS

Part	Purpose
1. Flow Meter	Measures and records flows into pond.
2. Bar Screen	Removes coarse material from pond influent.
3. Pond Inlets	Distribute influent in pond.
4. Pond Depth and Outlet Control	Regulates outflow from pond and depth of water in pond. Allows pond to be drained for cleaning and inspection.
5. Outlet Baffle	Prevents scum and other surface debris from flowing to next pond or receiving waters.
6. Dike or Levee	Separates ponds and holds wastewater being treated in ponds.
7. Transfer Line	Conveys wastewater from one pond to another.
8. Recirculation Line	Returns pond effluent rich in algae and oxygen from second pond to first pond for seeding, dilution and process control.
9. Chlorination	Applies chlorine to treated wastewater for disinfection purposes.
10. Chlorine Contact Basin	Provides contact time for chlorine to disinfect pond effluent.
11. Effluent Line	Conveys treated wastewater to receiving waters, to point of reuse (irrigation), or to land disposal site.

Dissolved nutrient materials, such as nitrogen and phosphorous, are utilized by green *ALGAE*[2] which are actually microscopic plants floating and living in the water. The algae use carbon dioxide (CO_2) and bicarbonate to build body protoplasm. In so growing, they need nitrogen and phosphorous in their metabolism much as land plants do. Like land plants, they release oxygen and some carbon dioxide as waste products.

Ponds can serve as very effective treatment facilities. Extensive studies of their performance have led to a better understanding of the natural processes by which ponds treat wastes. Information is provided here on the natural processes and ways operators can regulate pond processes for efficient waste treatment.

9.2 HISTORY OF PONDS IN WASTE TREATMENT

The first wastewater collection systems in the ancient Orient and in ancient Europe discharged wastewater into nearby bodies of water. These systems accomplished their intended purpose until overloading, as in modern systems, made them objectionable.

In ancient times, ponds and lakes were purposefully fertilized with organic wastes to encourage the growth of algae which, in turn, greatly increased the production of fish due to the food supply provided by the algae. This practice still continues and is a recognized art in Germany.

The first ponds constructed in the United States were built for the purpose of keeping wastewaters from flowing into places where they would be objectionable. Once built, these ponds performed a treatment process that finally became recognized as such.

The tendency over the years has been to equate pond treatment effiency with the non-emission of odors. Actually, the opposite is true as the greatest organic load destroyed per unit

---

[1] *Stabilized Wastes. A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.*

[2] *Algae (AL-gee). Microscopic plants which contain chlorophyll and float or are suspended and live in water. They also may be attached to structures, rocks or other similar substances.*

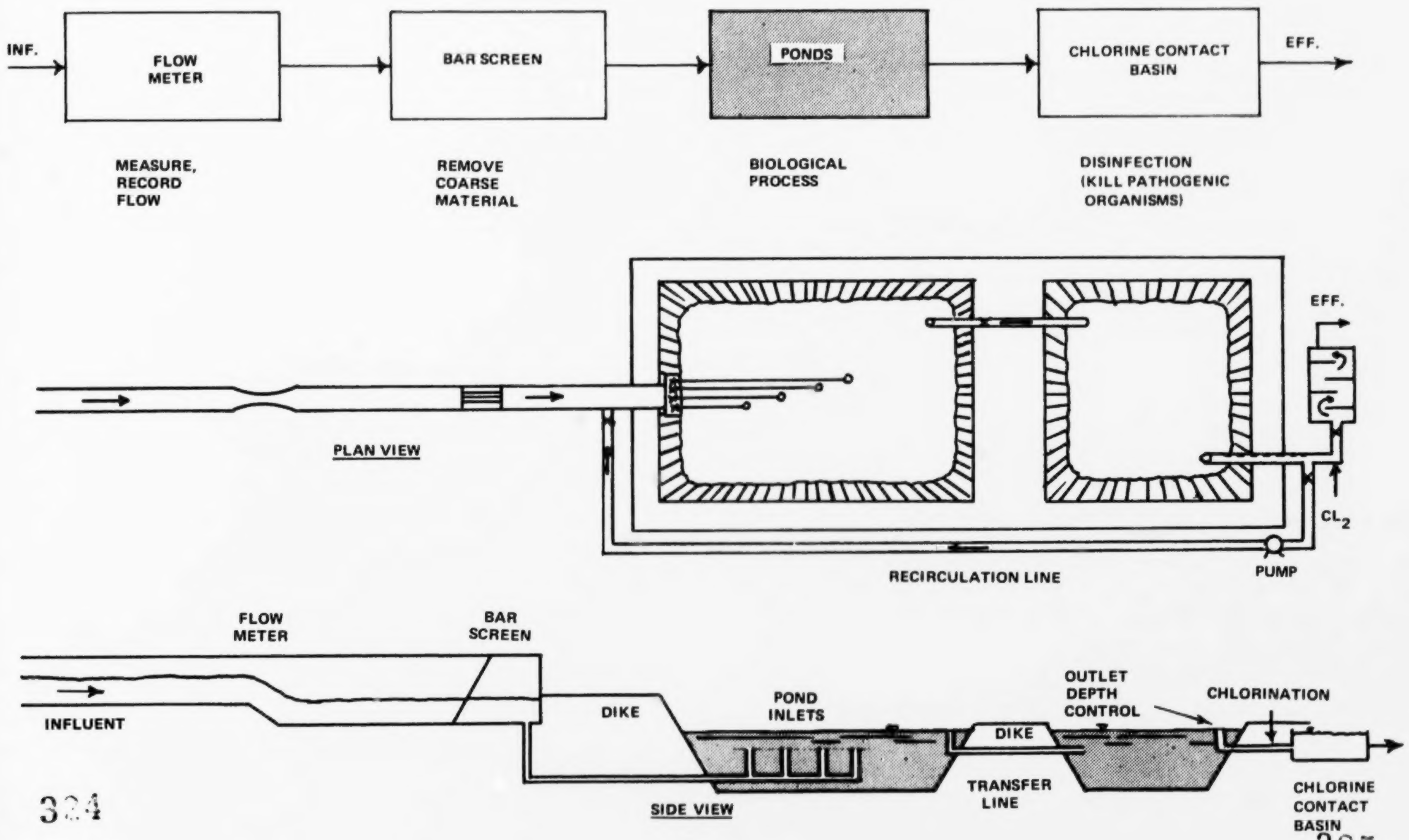

INF.
FLOW METER
BAR SCREEN
PONDS
CHLORINE CONTACT BASIN
EFF.
MEASURE, RECORD FLOW
REMOVE COARSE MATERIAL
BIOLOGICAL PROCESS
DISINFECTION (KILL PATHOGENIC ORGANISMS)
EFF.
PLAN VIEW
CL2
RECIRCULATION LINE
PUMP
FLOW METER
BAR SCREEN
INFLUENT
DIKE
POND INLETS
DIKE
OUTLET DEPTH CONTROL
CHLORINATION
TRANSFER LINE
SIDE VIEW
CHLORINE CONTACT BASIN

Fig. 9.1 Typical plant; ponds only

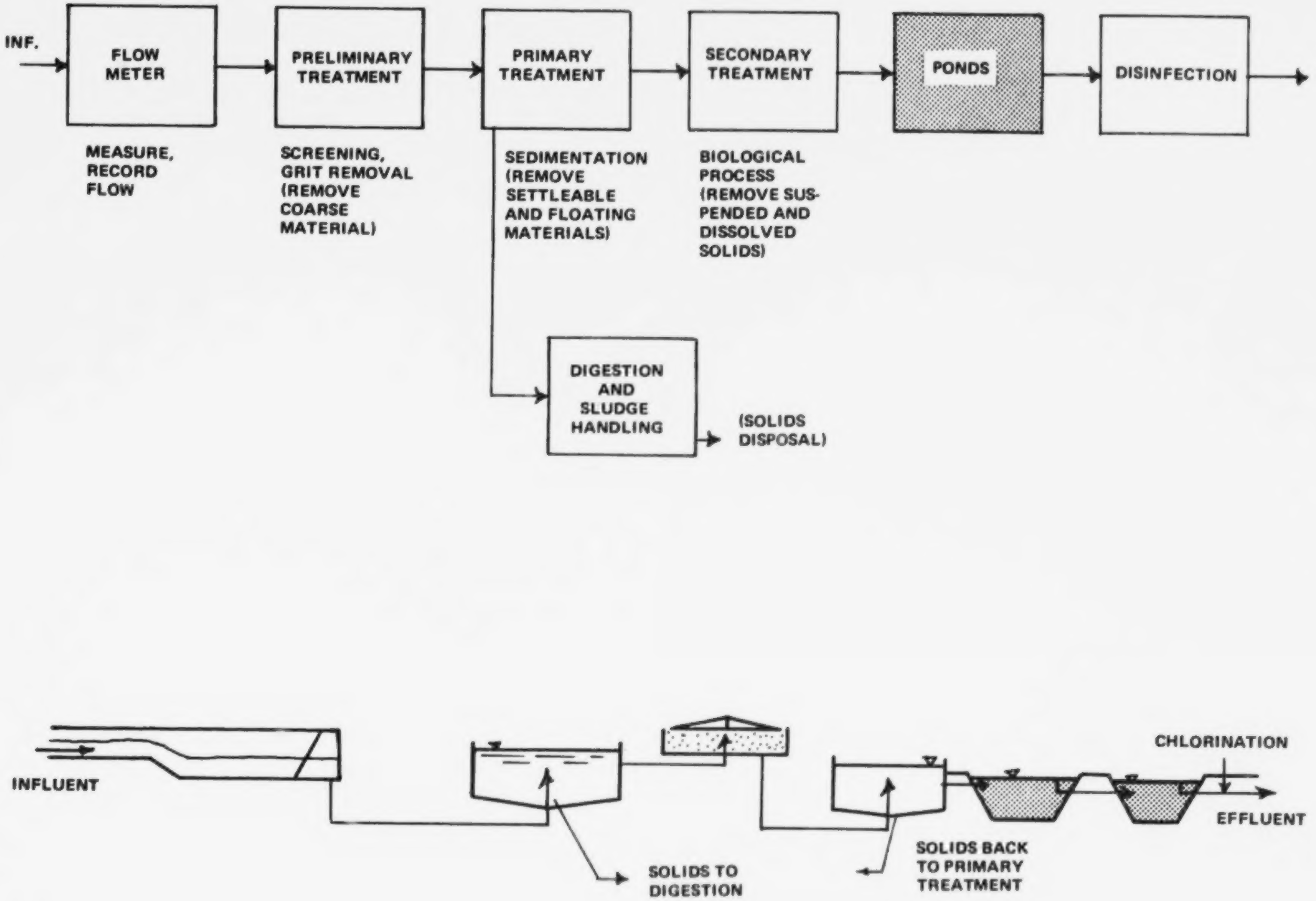

INF.
FLOW METER
PRELIMINARY TREATMENT
PRIMARY TREATMENT
SECONDARY TREATMENT
PONDS
DISINFECTION
MEASURE, RECORD FLOW
SCREENING, GRIT REMOVAL (REMOVE COARSE MATERIAL)
SEDIMENTATION (REMOVE SETTLEABLE AND FLOATING MATERIALS)
BIOLOGICAL PROCESS (REMOVE SUSPENDED AND DISSOLVED SOLIDS)
DIGESTION AND SLUDGE HANDLING
(SOLIDS DISPOSAL)
INFLUENT
CHLORINATION
EFFLUENT
SOLIDS TO DIGESTION
SOLIDS BACK TO PRIMARY TREATMENT

Fig. 9.2 Typical plant; ponds after secondary treatment

of area (high treatment efficiency) may be accompanied by objectionable odors.

Since 1958, engineers have designed and constructed a great number of ponds using research by qualified biological consultants, current scientific knowledge of ponding, and the experience of past successes and failures. When operated in a knowledgeable and purposeful manner, these ponds have successfully performed a variety of functions.

As a complete process, the ponding of wastewater offers many advantages for smaller installations. This is true provided that land is not costly and the location is isolated from residential, commercial, and recreational areas. The advantages are that a pond:

1. Does not require expensive equipment;
2. Does not require highly trained operating personnel;
3. Is economical to construct;
4. Provides treatment that is equal or superior to some conventional processes;
5. Is a satisfactory method of treating wastewater on a temporary basis;
6. Is adaptable to changing loads;
7. Is adaptable to land application;
8. Consumes little energy;
9. Serves as a wildlife habitat;
10. Has potentially an increased design life;
11. Has no sludge handling and disposal problems; and
12. Is probably the most trouble-free of any treatment process when utilized correctly, *PROVIDED A CONSISTENTLY HIGH QUALITY EFFLUENT IS NOT REQUIRED.*

The limitations are that a pond:

1. May emit odors;
2. Requires a large area of land;
3. Treats wastes somewhat dependent on climatic conditions;
4. May contaminate groundwaters; and
5. May have high suspended solids levels in the effluent.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 312.

9.2A If a pond is giving off objectionable odors, are the wastes being effectively treated? Explain your answer.

9.2B Discuss the advantages of ponds.

9.3 POND CLASSIFICATIONS AND APPLICATIONS

Ponding of raw wastewater, as a complete treatment process, is used to treat the wastes of single families as well as large cities up to the size of the city of Melbourne, Australia. Currently a portion of Melbourne's wastewater is disposed of on a 28,000 acre farm. During the dry season, most of the treatment is accomplished by broad irrigation and grass filtration (flowing through grass lands) while during the wet season most of the 130 MGD flow is handled by ponds and discharged to receiving waters. Ponds designed to receive wastes with no prior treatment are often referred to as "raw wastewater (sewage) lagoons" or "stabilization ponds" (Fig. 9.3). This requires sizable areas of land.

Ponds are quite commonly used in series (one pond following another) after a primary wastewater treatment plant to provide additional clarification, BOD removal, and disinfection. These ponds are sometimes called "oxidation ponds." Ponds are sometimes used in series after a trickling filter plant, thus giving a form of *TERTIARY*[3] treatment. These are sometimes called "polishing ponds." Ponds placed in series with each other can provide a high quality effluent which is acceptable for discharge into most watercourses. If the detention time is long enough, many ponds can meet fecal coliform standards.

A great many variations in ponds are possible due to differences in depth, operating conditions, and loadings. A bold line of distinction among different types of ponds is often impossible. Current literature generally uses three broad pond classifications: *AEROBIC, ANAEROBIC,* and *FACULTATIVE.*

AEROBIC ponds are characterized by having dissolved oxygen distributed throughout their contents practically all of the time. They usually require an additional source of oxygen to supplement the rather minimal amount that can be diffused from the atmosphere at the water surface. The additional source of oxygen may be supplied by algae during daylight hours, by mechanical agitation of the surface, or by bubbling air provided by compressors through the pond.

ANAEROBIC ponds, as the name implies, usually are without any dissolved oxygen throughout their entire depth. Treatment depends on fermentation of the sludge at the pond bottom. This process can be quite odorous under certain conditions, but it is highly efficient in destroying organic wastes. Anaerobic ponds are mainly used for processing industrial wastes, although some domestic-waste ponds become anaerobic when they are badly overloaded.

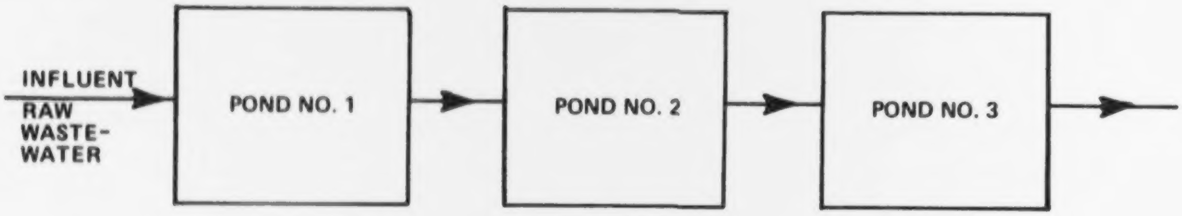
FACULTATIVE (FACK-ul-TAY-tive) ponds are the most common type in current use. The upper portion (supernatant) of these ponds is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant. Facultative ponds are most common because it is almost impossible to maintain completely aerobic or anaerobic conditions all the time at all depths of the pond.

Pond uses may be classified according to detention time. A pond with a detention time of less than three days will perform in ways similar to a sedimentation or settling tank. Some growth of algae will occur in the pond, but it will not have a major effect on the treatment of the wastewater.

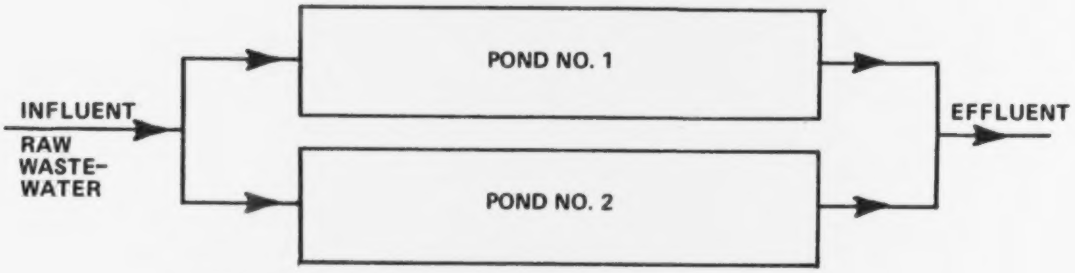
Prolific growth of algae will be observed in ponds with detention periods from three to around twenty days, but large amounts of algae will be found in the pond effluent. In some effluents, the stored organic material may be greater than the amount in the influent. Detention times in this range merely allow the organic material to change form and delay problems until the algae settle out in the receiving waters. Effluent BODs may show considerable reductions from influent BODs, but this is because BOD is a rate estimate (oxygen used during a

---

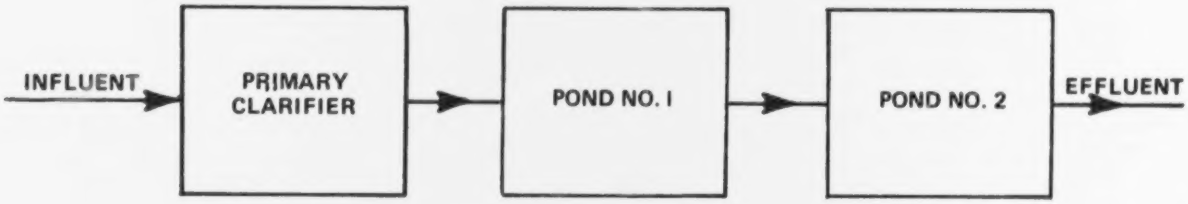
[3] *Tertiary (TER-she-AIR-ee). Tertiary refers to the third treatment process or the process following a secondary treatment process, such as a trickling filter. Some refer to tertiary treatment as advanced waste treatment, meaning processes that remove wastes not commonly removed by conventional (secondary) treatment processes.*


INFLUENT
RAW WASTE-WATER
POND NO. 1
POND NO. 2
POND NO. 3

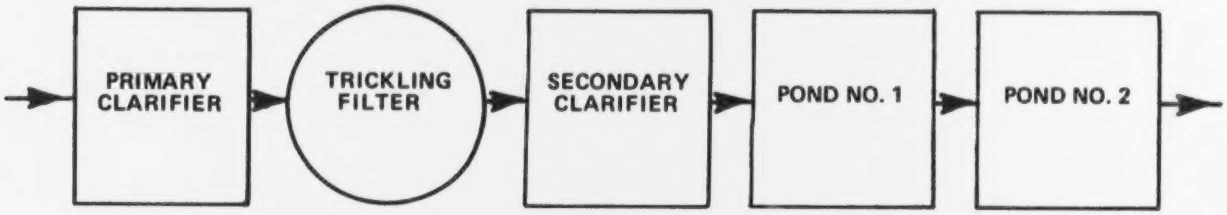
STABILIZATION PONDS IN SERIES


INFLUENT
RAW WASTE-WATER
POND NO. 1
POND NO. 2
EFFLUENT

STABILIZATION PONDS IN PARALLEL


INFLUENT
PRIMARY CLARIFIER
POND NO. I
POND NO. 2
EFFLUENT

OXIDATION PONDS IN SERIES


PRIMARY CLARIFIER
TRICKLING FILTER
SECONDARY CLARIFIER
POND NO. 1
POND NO. 2

POLISHING PONDS IN SERIES

Fig. 9.3 Pond Classifications

five-day period). The rate of oxygen use is temporarily slowed down, but will increase when anaerobic decomposition of settled dead algae cells starts.

Longer detention periods in ponds provide time for the sedimentation of algae. Usually, this will occur in ponds with anaerobic conditions on the bottom and aerobic conditions on the surface. Combined aerobic-anaerobic treatment provided by long detention periods produces definite stabilization of the influent.

Controlled discharge ponds are facultative ponds with long detention times of up to 180 days or longer. These ponds may discharge effluent only once (fall) or twice (fall and spring) a year.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 312.

9.3A What is the difference between raw wastewater (sewage) lagoons, oxidation ponds, and polishing ponds?

9.3B What is the difference between the terms "aerobic," "anaerobic," and "facultative" when applied to ponds?

9.3C How does the use of a pond vary depending on detention time?

9.4 EXPLANATION OF TREATMENT PROCESS

As mentioned in the previous section, waste disposal ponds also are classified according to their dissolved oxygen content. Oxygen in an aerobic pond is distributed throughout the entire depth practically all the time. An anaerobic pond is predominantly without oxygen most of the time because oxygen requirements are much greater than the oxygen supply. In a facultative pond, the upper portion is aerobic most of the time, whereas the bottom layer is predominantly anaerobic.

In aerobic ponds or in the aerobic layer of facultative ponds, organic matter contained in the wastewater is first converted to carbon dioxide and ammonia, and finally, to algae in the presence of sunlight. Algae are simple one-cell microscopic plants which are essential to the successful operation of both aerobic and facultative ponds.

By utilizing sunlight through *PHOTOSYNTHESIS*,[4] the one-celled plant uses the oxygen in the water molecule to produce *FREE OXYGEN*,[5] making it available to the aerobic bacteria that inhabit the pond. Each pound of algae in a healthy pond is capable of producing 1.6 pounds of oxygen on a normal summer day. Algae live on carbon dioxide and other nutrients in the wastewater. Algae occur naturally in a pond without seeding and multiply greatly under favorable conditions. Figure 9.4 illustrates the role of algae in treating wastes in a pond.

In anaerobic ponds or in the anaerobic layer of facultative ponds, the organic matter is first converted by a group of organisms called the "acid producers" to carbon dioxide, nitrogen, and organic acids. In an established pond, at the same time, a group called the "methane fermenters" breaks down the acids and other products of the first group to form methane gas and alkalinity. Water is another end product of organic decomposition. This process is described in Figure 9.4.

In a successful facultative pond, the processes characteristic of aerobic ponds occur in the surface layers, while those similar to anaerobic ponds occur in its bottom layers.

During certain periods, sludge decomposition in the anaerobic zone is interrupted and it begins to accumulate. If sludge accumulation occurs and decomposition does not set in, it is probably due to a lack of the right bacteria, low *pH*,[6] presence of substances that slow or stop the process, or a low temperature. Under these circumstances, the acid production will continue at a slower rate, but the rate of gas (methane) production slows down considerably.

Sludge storage in ponds is continuous with small amounts stored during warm weather and larger amounts when it is cold. During low temperatures, the bacteria cannot multiply fast enough to handle the waste. When warm weather comes, the "acid producers" begin to decompose the accumulated sludge deposits built up during the winter. If the organic acid production is too great, a lowered pH will occur with the possibilities of an upset pond and resulting hydrogen sulfide odors.

Hydrogen sulfide ordinarily is not a problem in properly designed and operated ponds because it dissociates (divides) into hydrogen and hydrosulfide ions at high pH and may form insoluble metallic sulfides or sulfates. This high degree of dissociation and the formation of insoluble metallic sulfides are the reasons that ponds having a pH above 8.5 do not emit odors, even when hydrogen sulfide is present in relatively large amounts. An exception occurs in northern climates during the spring when the pH is low and the pond is just getting started, then hydrogen sulfide odors can be a problem.

All of the organic matter that finds its way to the bottom of a stabilization pond through the various processes of sludge decomposition is subject to *METHANE FERMENTATION*, provided that proper conditions exist or become established. In order for methane fermentation to exist, an abundance of organic matter must be deposited and continually converted to organic acids. An abundant population of methane bacteria must be present. They require a pH level of from 6.5 to 7.5 within the sludge, alkalinity of several hundred mg/*L* to buffer (neutralize) the organic acids (volatile acid/alkalinity relationship), and suitable temperatures. Once methane fermentation is established, it accounts for a considerable amount of the organic load removal.

---

[4] *Photosynthesis. A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. Land plants grow by the same process.*

$$CO_2 + H_2O \xrightarrow{Light} CH_2O_X + O_2$$

[5] *Free Oxygen. Molecular oxygen available for respiration by organisms. Molecular oxygen is the oxygen molecule, O_2, that is not combined with another element to form a compound.*

[6] *pH. pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.*

$$pH = Log \frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is the most acid, 14 the most basic, and 7 is neutral. Most natural waters usually have a pH between 6.5 and 8.5.

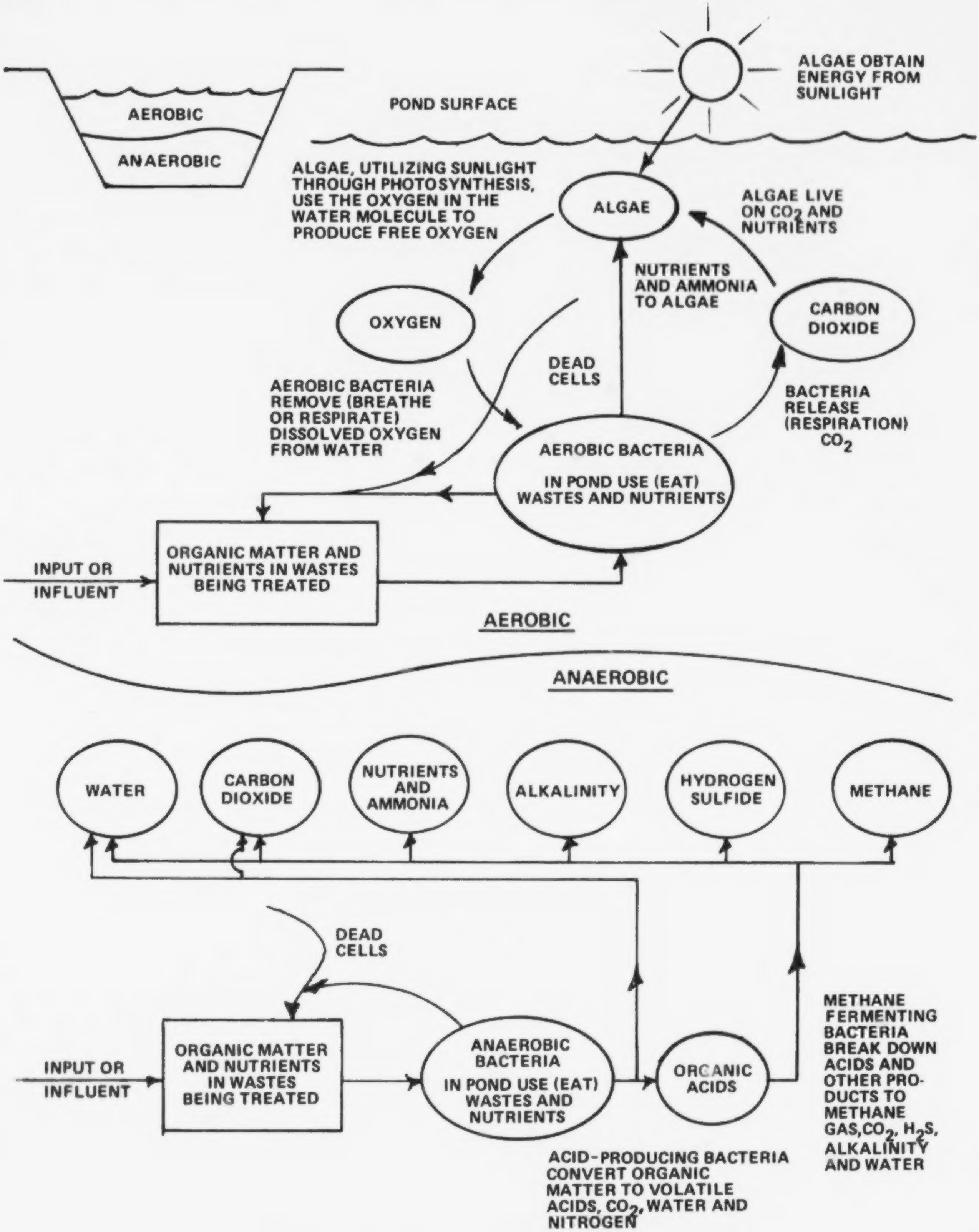

AEROBIC
ANAEROBIC
POND SURFACE
ALGAE OBTAIN ENERGY FROM SUNLIGHT
ALGAE, UTILIZING SUNLIGHT THROUGH PHOTOSYNTHESIS, USE THE OXYGEN IN THE WATER MOLECULE TO PRODUCE FREE OXYGEN
ALGAE
ALGAE LIVE ON CO_2 AND NUTRIENTS
NUTRIENTS AND AMMONIA TO ALGAE
OXYGEN
CARBON DIOXIDE
DEAD CELLS
AEROBIC BACTERIA REMOVE (BREATHE OR RESPIRATE) DISSOLVED OXYGEN FROM WATER
BACTERIA RELEASE (RESPIRATION) CO_2
AEROBIC BACTERIA IN POND USE (EAT) WASTES AND NUTRIENTS
INPUT OR INFLUENT
ORGANIC MATTER AND NUTRIENTS IN WASTES BEING TREATED
AEROBIC
ANAEROBIC
WATER
CARBON DIOXIDE
NUTRIENTS AND AMMONIA
ALKALINITY
HYDROGEN SULFIDE
METHANE
DEAD CELLS
METHANE FERMENTING BACTERIA BREAK DOWN ACIDS AND OTHER PRODUCTS TO METHANE GAS, CO_2, H_2S, ALKALINITY AND WATER
INPUT OR INFLUENT
ORGANIC MATTER AND NUTRIENTS IN WASTES BEING TREATED
ANAEROBIC BACTERIA IN POND USE (EAT) WASTES AND NUTRIENTS
ORGANIC ACIDS
ACID-PRODUCING BACTERIA CONVERT ORGANIC MATTER TO VOLATILE ACIDS, CO_2, WATER AND NITROGEN

Fig. 9.4 Process of decomposition in aerobic and anaerobic layers of a pond

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 312.

9.4A How is oxygen produced by algae?

9.4B Where does the algae found in a pond come from?

9.4C What happens to unstable organic matter in a pond?

9.5 POND PERFORMANCE

The treatment efficiencies that can be expected from ponds vary more than most other treatment devices. Some of the many variables are:

1. Physical Factors
    a. type of soil
    b. surface area
    c. depth
    d. wind action
    e. sunlight
    f. temperature
    g. short-circuiting
    h. inflow variations
2. Chemical Factors
    a. organic material
    b. pH
    c. solids
    d. concentration and nature of waste
3. Biological Factors
    a. type of bacteria
    b. type and quantity of algae
    c. activity of organisms
    d. nutrient deficiencies
    e. toxic concentrations

The performance expected from a pond depends largely upon its design. The design, of course, is determined by the waste discharge requirements or the water quality standards to be met in the receiving waters. Overall treatment efficiency may be about the same as primary treatment (only settling of solids), or it may be equivalent to the best secondary biological treatment plants. Some ponds, usually those located in hot, arid areas, have been designed to take advantage of *PERCOLATION*[7] and high evaporation rates so that there is no discharge.

Depending on design, ponds can be expected to provide BOD removals from 50 to 90 percent. Facultative ponds, under normal design loads with 50 to 60 days' detention time, will usually remove approximately 90 to 95 percent of the coliform bacteria and 70 to 80 percent of the BOD load approximately 80 percent of the time. Controlled discharge ponds with 180-day detention times can produce BOD removals from 85 to 95 percent, total suspended solids removals from 85 to 95 percent, and fecal coliform reductions up to 99 percent.

Physical sedimentation by itself has been found to remove approximately 90 percent of the suspended solids in three days. About 80 percent of the dissolved organic solids can be removed by biologic action in ten days. However, in a pond with a healthy algae and bacteria population, a phenomenon known as *BIOFLOCCULATION*[8] can occur. This will remove approximately 85 percent of both suspended and dissolved solids within hours. Bioflocculation is accelerated by increased temperature, wave action, and high dissolved oxygen content.

Pond detention times are sometimes specified by regulatory agencies to assure adequate treatment and removal of bacteria. Many agencies specify effluent or receiving water quality standards in terms of *MEDIAN*[9] and maximum MPN (Most Probable Number) values that should not be exceeded. In critical water use areas, chlorination or other means of disinfection can be used to further reduce the coliform level (see Chapter 10, "Chlorination and Disinfection").

A pond is generally regarded as not fulfilling its function when it creates a visual or odor nuisance, or leaves a high BOD, solids, grease, or coliform-group bacteria concentration in the discharge.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 312.

9.5A What is bioflocculation?

9.5B What biological factors influence the treatment efficiency of a pond?

9.5C What factors indicate that a pond is not fulfilling its function (operating properly)?

END OF LESSON 1 OF 3 LESSONS
ON
WASTE TREATMENT PONDS

Please answer the discussion and review questions before continuing with Lesson 2.

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[7] *Percolation (PURR-ko-LAY-shun). The movement or flow of water through soil or rocks.*

[8] *Bioflocculation (BUY-o-flock-u-LAY-shun). The clumping together of fine, dispersed organic particles by the action of bacteria and algae. This results in faster and more complete settling of the organic solids in wastewater.*

[9] *Median. The middle measurement or value. When several measurements are ranked by magnitude (largest to smallest), half of the measurements will be larger and half will be smaller.*

DISCUSSION AND REVIEW QUESTIONS

Chapter 9. WASTE TREATMENT PONDS

(Lesson 1 of 3 Lessons)

At the end of each lesson in this chapter, you will find some discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in this lesson.

Write the answers to these questions in your notebook before continuing.

1. When wastewater flows through different treatment processes in a plant, where might ponds be located?
2. Why are most ponds "facultative ponds"?
3. Where does the oxygen come from that is produced by algae in a pond?
4. What is photosynthesis?
5. What are the three types of factors that may influence pond performance?

CHAPTER 9. WASTE TREATMENT PONDS

(Lesson 2 of 3 Lessons)

9.6 STARTING THE POND

One of the most critical periods of a pond's life is the time that it is first placed in operation. If at all possible, at least one foot (0.3 m) of water should be in the pond before wastes are introduced. The water should be turned into the pond in advance to prevent odors developing from waste solids exposed to the atmosphere. Thus a source of water should be available when starting a pond.

A good practice is to start ponds during the warmer part of the year because a shallow starting depth allows the contents of the pond to cool too rapidly if nights are cold. Generally speaking, the warmer the pond contents, the more efficient the treatment processes.

Algal blooms normally will appear from seven to twelve days after wastes are introduced into a pond, but it generally takes at least sixty days to establish a thriving biological community. A definite green color is evidence that a flourishing algae population has been established. After this length of time has elapsed, bacterial decomposition of bottom solids will usually become established. This is generally evidenced by bubbles coming to the surface near the pond inlet where most of the sludge deposits occur. Although the bottom is anaerobic, travel of the gas through the aerobic surface layers generally prevents odor release.

Wastes should be discharged to the pond intermittently during the first few weeks with constant monitoring of the pH. The pH in the pond should be kept above 7.5 if possible. Initially the pH of the bottom sludge will be below 7 due to the digestion of the sludge by acid-producing bacteria. If the pH starts to drop, discharge to the pond should be diverted to another pond or diluted with make-up water (water from another source) if another pond is not available until the pH recovers. A high pH is essential to encourage a balanced anaerobic fermentation (bacterial decomposition) of bottom sludge. This high pH also is indicative of high algal activity since removal of the carbonate from the water in algal metabolism tends to keep the pH high. A continuing low pH indicates acid production which will cause odors. Soda ash (sodium carbonate) may be added to the influent to a pond to increase the pH.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 312.

9.6A Why should at least one foot of fresh water cover the pond bottom before wastes are introduced?

9.6B Why should ponds be started during the warmer part of the year if at all possible?

9.6C What does a definite green color in a pond indicate?

9.6D When bubbles are observed coming to the pond surface near the inlet, what is happening in the pond?

9.7 DAILY OPERATION AND MAINTENANCE

BECAUSE PONDS ARE DECEPTIVELY SIMPLE, THEY ARE PROBABLY NEGLECTED MORE THAN ANY OTHER TYPE OF WASTEWATER TREATMENT PROCESS. Many of the complaints that arise regarding ponds are the result of neglect or poor housekeeping. Following are listed the day-to-day operational and maintenance duties that will help to insure peak treatment efficiency and to present your plant to its neighbors as a well-run waste treatment facility. If problems develop in a pond, refer to this section and Section 9.11, "Review of Plans and Specifications," as troubleshooting guides.

9.70 Scum Control

Scum accumulation is a common characteristic of ponds and is usually greatest in the spring of the year when the water warms and vigorous biological activity resumes. Ordinarily, wind action will dissipate scum accumulations and cause them to settle; however, in the absence of wind or in sheltered areas, other means must be used. If scum is not broken up, it will dry on top and become crusted. Not only is the scum more difficult to break up then, but a species of blue-green algae is apt to become established on the scum. This can give rise to disagreeable odors. If scum is allowed to accumulate, it can reach proportions where it cuts off a significant amount of sunlight from the pond. When this happens the production of oxygen by algae is reduced and odor problems can result. Rafts of scum cause a very unsightly appearance in ponds and can quite likely become a source of botulism that will have a devastating effect on waterfowl and shore birds which may be attracted to the facility.

Many methods of breaking up scum have been used, including agitation with garden rakes from the shore, jets of water from pumps or tank trucks, and the use of outboard motors on boats in large ponds. Outboard motors should be of the air-cooled type to avoid plugging the cooling system with algae and scum. Scum is broken up most easily if it is attended to promptly.

9.71 Odor Control

Eventually, at some time, odors probably will come from a wastewater treatment plant no matter what kind of process is used. Most odors are caused by overloading (see Section 9.119 to determine pond loading) or poor housekeeping practices and can be remedied by taking corrective measures. If a pond is overloaded, stop loading and divert influent to other ponds, if available, until the odor problem stops. Then gradually start loading the pond again. Once a pond develops odor problems, it is more apt to cause trouble than other ponds.

There are times, such as when unexpected shutdowns occur, that plant processes may be upset and cause odors. For these unexpected occurrences, it is strongly advised that a careful plan for emergency odor control be available. Odors usually occur during the spring warmup in colder climates because biological activity has been reduced during cold weather. When the water warms, microorganisms become active, use up all of the available dissolved oxygen, and odors are produced under these anaerobic conditions.

There are several suggested ways to reduce odors in ponds. These ways include recirculation from aerobic units, the use of floating aerators, and heavy chlorination. Recirculation from an aerobic pond to the inlet of an anaerobic pond (1 part recycle flow to 6 parts influent flow) will reduce or eliminate odors. Usually, floating aeration and chlorination equipment are too expensive to have standing idle waiting for an odor problem to develop. Odor-masking chemicals also have been promoted for this purpose and have some uses for concentrated sources of specific odors. However, in almost all cases, process procedures of the type mentioned previously are preferable. In any event, it is poor procedure to wait until the emergency arises to plan for odor control. Often several days are needed to receive delivery of materials or chemicals if they are required. Try to have possible alternate methods of control ready to go in case they are needed.

In some areas, sodium nitrate has been added to ponds as a source of oxygen for microorganisms rather than sulfate compounds, already in the water, thus preventing odors. To be effective, sodium nitrate must be dispersed throughout the water in the pond. Once mixed in the pond, it acts very quickly because may common organisms (facultative groups) may use the oxygen in nitrate compounds instead of dissolved oxygen. Liquid sodium hypochlorite or chlorine solution is a faster acting solution, but not necessarily the best chemical because it will interfere with biological stabilization of the wastes.

9.72 Weed and Insect Control

Weed control is an essential part of good housekeeping and is not a formidable task with modern herbicides and soil sterilants. Weeds around the edge are most objectionable because they allow a sheltered area for mosquito breeding and scum accumulation. In most average ponds, there has been little need for mosquito control when edges are kept free of weed growth. Weeds also can hinder pond circulation. Aquatic weeds, such as tules, will grow in depths shallower than three feet (1 m), so an operating pond level of at least this depth is necessary. Tules may emerge singly or be well scattered, but should be removed promptly by hand as they will quickly multiply from the root system. One of the best methods for control of undesirable vegetation is achieved by a daily practice of close inspection and immediate removal of the young plants (including roots).

Suspended vegetation, such as duckweed, usually will not flourish if the pond is exposed to a clean sweep of the wind. Dike vegetation control is aided by regular mowing and use of a cover grass that will outcompete undesirable growth. Because emergent weed growth will occur only when sunlight is able to reach the pond bottom, the single best preventive measure against emergent growth is to maintain a water depth of at least three feet. Due to greater water clarity, the amount of sunlight reaching the bottom will be greater in secondary or final ponds than in primary ponds. Because shallow water promotes growth, there will likely always be a battle to keep emergent weeds from becoming well-established around lagoon banks.

Whenever emergent or suspended weeds are being pulled from the lagoon, such protective gear as waterproof gloves, boots and goggles should be worn to reduce the chance of infection from pathogens that may be present in the water. Pulled weeds should be buried to prevent odor and insect problems. Although most stabilization ponds are no deeper than five feet, there is still sufficient depth to drown a person, especially if that person gets caught in a sticky clay liner. Using the buddy system and life preservers will greatly increase the safety level when performing any pond maintenance, especially when using a boat or mowing the dike.

Control measures include:

Emergent Weeds -

1. Keep the water level above three feet.
2. Pull out new (first-year) growth by hand.
3. Drown the weeds by raising the water level.
4. Lower the water level, cut the weeds or burn them with a gas burner, and raise the water level (cut and drown).
5. Use herbicides as a last resort.
6. Use rip-rap (large broken stones or concrete) along the bank. If rip-rap is used and growth continues, herbicides will be the only alternative.
7. Install a pond liner.

Suspended Vegetation -

1. Keep the pond exposed to a clean sweep of the wind.
2. A few ducks may be used to eat light growth of duckweed.
3. Small ponds may be skimmed with rakes or boards. This may have to be repeated.
4. Excessive growth can be mechanically harvested.
5. Use herbicides as a last resort.

Dike Vegetation -

1. Mow regularly during the growing season. Dike slopes may be cut using sickle bars or weed-eater equipment. When using heavy equipment, mowers designed especially for cutting slopes are preferable. Any tractor used on the dike should have a low center of gravity.
2. Seed or re-seed slopes with desirable grasses that will form a thick and somewhat impenetrable mat.
3. Use the small grazing animals such as sheep, but be aware of the disadvantages, including (a) increase in fecal coliform (especially in secondary or final ponds), (b) possible complication of erosion problems, and (c) possible destruction of desirable grasses if rotational grazing is not practiced.
4. Use herbicides as a last resort.

Herbicides are a last resort in vegetation control for ponds, not only because of the obvious hazards facing the operator, but also because of dangers presented to the biological growth in the pond and receiving stream (if discharging).

Care must be taken to follow mixing, application and storage directions exactly. Safety for the operator and for any other persons who might come in contact with the herbicide is of utmost importance. Proper protective gear and warnings (verbal and written) are vital. Also, desirable vegetation could be killed by herbicide drift on a windy day or by other improper applications.

Availability, formulation, trade names, federal clearance of state registration for certain herbicides may change. Do not use stored herbicides without checking on their current status of approval.

Some herbicides are effective only on certain plants, and herbicides are most effective at specific stages in the life of the plant. Cattails, for instance, are usually sprayed when the shoots are two to three feet tall and cattails are developing.

Perhaps the most important factor in the selection of the proper herbicide is site compatibility. In addition to the other important instructions on the product label, a comprehensive listing of approved application sites is usually provided. This list should be checked to verify that the product is the best choice for each specific application. Herbicides that are effective on many types of undesirable lagoon vegetation, and that are approved for both pond and river (discharging lagoon) applications are often the logical choice.

Duckweed consists of tiny green plants that float on the surface of a pond. Duckweed stops sunlight penetration and hinders surface aeration, thus reducing dissolved oxygen in the pond. Rakes, water sprays or pushing a board with a boat can be used to move the duckweed into a corner of a pond where it can be physically removed from the pond. Another approach is to install a surface discharge in the downwind corner of a pond. The prevailing winds will blow the duckweed into the corner and the duckweed will be removed by the surface discharge. The duckweed can be captured by a wire mesh bucket placed in the effluent line after the surface outlet. The bucket will need to be removed and cleaned as the duckweed accumulates.

Mosquitoes will breed in sheltered areas of standing water where there is vegetation or scum to which the egg rafts of the female mosquito can become attached. These egg rafts are fragile and will not withstand the action of disturbed water surfaces such as caused by wind action or normal currents. Keeping the water edge clear of vegetation and keeping any scum broken up will normally give adequate control. Shallow, isolated pools left by the receding pond level should be drained or sprayed with a larvacide.

Any of several minute shrimp-like animals may infest the pond from time to time during the warmer months of the year (March - November). These predators live on algae and at times will appear in such numbers as to almost clear the pond of algae. During the more severe infestations, there will be a sharp drop in the dissolved oxygen of the pond, accompanied by a lowered pH. This is a temporary condition because the predators will outrun the algae supply, and there will be a mass die-off of insects which will be followed by a rapid greening up of the pond again. When the algae concentration in a pond is low under these conditions, ponds operated on a batch basis may find this a good time for release of water due to low suspended solids values.

Ordinarily there should be no great concern about these infestations because they soon balance themselves; however, in the case of a heavily loaded pond, a sustained low dissolved oxygen content may give rise to noxious odors. In that event, any of several commercial sprays can be used to control the shrimp-like animals.

Chironomid midges are often produced in wastewater ponds in sufficient numbers to be serious nuisances to nearby residential areas, farm workers, recreation sites, and industrial plants. When emerging in large numbers, they may also create traffic hazards. At present the only satisfactory control is through the use of insecticides. Control measures are time consuming and may be difficult, particularly if there is a discharge to a receiving stream. If possible, lower the level in the ponds enough to contain a day's inflow before applying an insecticide. Holding the insecticide for at least one day will kill more insects and reduce the effect of the insecticide on receiving waters. For better results, insecticides should be applied on a calm day and any recirculation pumps should be stopped.

CAUTION. Before attempting to apply any insecticide or pesticide, contact your local official in charge of approving pesticide applications. This person can tell you which chemicals may be applied, the conditions of application, and safe procedures.

9.73 Levee Maintenance

Levee slope erosion caused by wave action or surface runoff from precipitation is probably the most serious maintenance problem. If allowed to continue, it will result in a narrowing of the levee crown which will make accessibility with maintenance equipment most difficult.

If the levee slope is composed of easily erodible material, one long-range solution is the use of bank protection such as stone *RIPRAP*[10] or broken concrete rubble. Good sources of bank-protection materials include small pieces of broken street materials, curbs, gutters, and also bricks and other suitable materials from building demolition. Also a semi-porous plastic sheet has been used with riprap. This sheet allows the two-way movement of air and water, but prevents the movement of soils. The sheet also discourages weed growth and digging by crayfish (crawdads).

Portions of the pond levee or dike not exposed to wave action should be planted with a low-growing spreading grass to prevent erosion by surface runoff. Native grasses may naturally seed the levees, or local highway departments may be consulted for suitable grasses to control erosion. If necessary, grass may have to be mowed to prevent it from becoming too high. Do not allow grazing animals to control vegetation because they may damage the levees near the water line and possibly complicate erosion problems.

Plants or grasses with long roots, such as willows and alfalfa, should not be allowed to grow on levees because they may damage the levees and possibly cause levee failure and costly repair. Burrowing animals such as muskrats, badgers, squirrels and gophers also may cause levees to fail. Remove these animals from levees as soon as possible and repair their burrowed holes immediately.

Levee tops should be crowned so that rain water will drain over the side in a sheet flow. Otherwise the water may flow a considerable distance along the levee crown and gather enough flow to cause erosion when it finally spills over the side and down the slope.

If the levees are to be used as roadways during wet weather, they should be paved or well graveled.

If seepage or leakage from the ponds appears on the outside of levees, ask your engineer to investigate and solve this problem before further damage occurs to the levee.

9.74 Headworks and Screening

Be sure to clean the bar screen as frequently as necessary. The screen should be inspected at least once or twice a day with more frequent visits during storm periods. Screenings should be disposed of daily in a sanitary manner, such as by burial, to avoid odors and fly breeding. A trench dug by a backhoe near the bar screen provides a convenient location for disposal by burial. Another method of disposal is to place screenings in garbage cans and request that your local garbage service dispose of the screenings at a sanitary-landfill disposal site.

Many pond installations have grit chambers at the headworks to protect raw-wastewater lift pumps or prevent plugging of the influent lines. There are many types of grit-removal equipment. Grit removed by the various types of mechanical equipment or by manual means will usually contain small amounts of organic matter and should therefore be disposed of in a sanitary manner. Disposal by burial is the most common method.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 312.

9.7A Why should scum not be allowed to accumulate on the surface of a pond?

9.7B How can scum accumulations be broken up?

9.7C What are the causes of odors from a pond?

9.7D What precaution would you take to be prepared for an odor problem which might develop?

9.7E Why are weeds objectionable in and around ponds?

9.7F How can weeds be controlled and removed in and around ponds?

9.7G Why should insects be controlled?

9.7H Why should a pond be lowered before an insecticide is applied?

9.75 Some Operating Hints

1. Anaerobic ponds should be covered and isolated for odor control and followed by aerobic ponds. Floating polystyrene planks can be used to cover anaerobic ponds and can be painted white for protection from the sun. These will help to confine odors and heat and tend to make the anaerobic ponds more efficient.
2. Placing *PONDS IN SERIES*[11] tends to cause the first pond to become overloaded and may never allow it to recover; the overload may be carried to the next pond in series. Feeding *PONDS IN PARALLEL*[11] allows you to distribute the incoming load evenly between units. Whether ponds are operated in series or in parallel should depend on the loading situation.

   When operating ponds in series, the accumulation of solids in the first pond may become a serious problem after a long period of use. Periodically the flow should be routed around the first pond. This pond should then be drained and the solids removed and buried.
3. A large amount of recirculation, say 25 to 100 percent, can be very helpful. This allows the algae and other aerobic organisms to become thoroughly mixed with incoming raw wastewater. At the same time, good oxygen transfer can be

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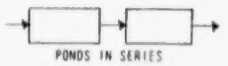
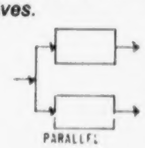
[10] *Riprap. Broken stones, boulders, or other materials placed compactly or irregularly on levees or dikes for the protection of earth surfaces against the erosive action of waves.*

[11]





attained by passing the incoming water over a deck and down steps or other type of aerator. This procedure can cause heat loss, however.

4. Heavy chlorination at the recirculation point can assist in odor control, but will probably interfere with treatment.
5. As with any treatment process, it is necessary to measure the important water quality indicators (DO and solids) at frequent, regular intervals and plot them so that you have some idea of the direction the process is taking in time to take corrective action when necessary.
6. When solids start floating to the surface of a pond during the spring or fall overturn, the pond may have to be taken out of service and cleaned. Measurement of the sludge depth on the bottom of a pond also will indicate when a pond should be cleaned. Usually ponds are cleaned when the wet sludge depth is over one-foot (0.3 m) deep.
7. Before applying insecticides or herbicides, be sure to check with appropriate authorities regarding the long-term effects of the pesticide you plan to use. Do not apply pesticides that may be toxic to organisms in the receiving waters.
8. Algae in effluent. Unfortunately there is little an operator can do by changing pond operating procedures to effectively remove algae from a pond effluent. The best approach is to operate ponds in series and to draw off the effluent below the surface by use of a good baffling arrangement.

   If the algae must be removed from the effluent of a pond, additional facilities may be designed and constructed. Techniques for eliminating algae from pond effluents include growing a water hyacinth culture in a special final pond (see Section 9.12, "Eliminating Algae from Pond Effluent"). Suitable effluents have been obtained under favorable field conditions. Other algae removal processes include microscreening, slow sand filtration, dissolved air flotation, and algae harvesting. In final ponds that are operated in series with periodic discharges, alum may be added in doses of less than 20 mg/*L* to improve effluent quality before discharge.

9.76 Abnormal Operation

Abnormal operation occurs when ponds are overloaded because the BOD loads are too high. Excessive BODs can occur when influent loads exceed design capacity due to population increases, industrial growth, or industrial dumps. Under these conditions new facilities must be constructed or the BOD loading must be reduced at the source, such as an industrial dump.

Another type of overloading can occur when too much flow is diverted to one pond. This can happen when an operator accidentally feeds one pond more than the other or when a pipe opening is blocked by rags, solids or grit due to low pipe velocities, and thus too much flow is diverted to another pond. When this happens and the overloaded pond starts producing odors, take the pond out of service and divert flows to the other ponds until the overloaded pond recovers. Hopefully the ponds in service will not become overloaded. Also be sure to remove any rags, solids or grit which caused the overloading and inspect the other pipes to prevent this problem from happening again in the other ponds.

Usually ponds do not become overloaded during storms and periods of high runoff because there is not a significant increase in the BOD loading on the ponds.

Large amounts of brown or black scum on the surface of a pond is an indication that the pond is overloaded. Scum on the surface of a pond often leads to odor problems. The best way to control scum is to take corrective action as soon as possible (see Section 9.70, "Scum Control").

During winter conditions the pond can become covered with ice and snow. Sunlight is no longer available to the algae and oxygen cannot enter the water from the atmosphere. Without dissolved oxygen available for aerobic decomposition, anaerobic decomposition of the solids occurs. Anaerobic decomposition takes place slowly because of the low temperatures. By keeping the pond surface at a high level, a longer detention time and less heat loss will be obtained. During the period of ice cover, odorous gases formed by anaerobic decomposition accumulate under the ice and are dissolved into the wastewater being treated.

Some odors may be observed in the spring just after the ice cover breaks up because the pond is still in an anaerobic state and some of these dissolved gases are being released. Melting of ice in the spring provides dilution water with a high oxygen content, thus the ponds usually become facultative in a few days after breakup of the ice if they are not organically (BOD) overloaded.

9.77 Batch Operation

Some ponds do not discharge continuously. These ponds may discharge only once (fall) or twice (fall and spring) a year. Discharges should be made only when necessary and, if possible, during the nonrecreational season when flows are high in the receiving waters.

If your pond is allowed to discharge intermittently (controlled discharge), you must work closely with your pollution control agency and be sure that you are in compliance with the National Pollutant Discharge Elimination System (NPDES) permit. Before and during the discharge, samples should be collected from the pond being emptied and from the receiving waters both upstream and downstream from the point of discharge. Samples are usually analyzed for DO, BOD, pH, total suspended solids, and coliform-group bacteria.

Ponds should not be emptied too quickly. Usually ponds are emptied in two weeks or less depending on how much water is to be discharged. Normally one to one and a half feet (0.3 to 0.45 m) of water is left in the bottom of the pond.

9.78 Shutting Down a Pond

Ponds may be shut down for short periods of time without any problems developing. For example, if flow to a pond must be stopped to repair a pipe or a valve, no precautionary procedures are necessary. If a pond is full and received no flows for a long period of time, start up the pond with caution and gradually increase the load. If the full load is applied immediately, the pond may become overloaded because the microorganism population in the pond is low and insufficient to treat the load.

Stop all flow to a pond when emptying it to remove bottom deposits, repair inlet or outlet structures, or repair levees. Drain by use of discharge valves or pump water from one pond to other ponds. Try to feed the other ponds equally to prevent them from becoming overloaded. Frequently there is a time lag between the overloading of a pond and the development of problems. Therefore, watch the other ponds and lab results closely for any signs (odors, low pH, low DO, drop in alkalinity, loss of green color) of potential problems developing.

9.79 Operating Strategy

In order to prevent your ponds from developing odors or discharging an effluent in violation of the NPDES permit requirements, you should develop a plan to keep your ponds operating as intended.

A. Maintain constant water elevations in the ponds.

If your NPDES permit allows the discharge of a pond into receiving waters, keep a constant water level to help maintain constant loadings. When the water surface elevation starts to drop, look for the following possible causes:

1. Discharge valve open too far or a *STOP LOG*[12] is missing;
2. Levees leaking due to animal burrows, cracks, soil settlement or erosion; and
3. Inlet lines plugged or restricted and causing wastewater to back up into the collection system.

When the water surface starts to rise, look for:

1. Discharge valve closed or lines plugged, and
2. Sources of infiltration.

NOTE: Under some conditions you may not want to maintain constant water levels in your ponds. For example, you may allow the water surface to fluctuate to

1. Control shoreline aquatic vegetation,
2. Control mosquito breeding and burrowing rodents,
3. Handle fluctuating inflows, and
4. Regulate discharge (continuous, intermittent or seasonal).

B. Distribute inflow equally to ponds.

All ponds designed to receive the flow should receive the same hydraulic and organic (BOD) loadings.

C. Keep pond levees or dikes in good condition.

Proper maintenance of pond levees can be a time-saving activity. Regularly inspect levees for leaks and erosion and correct any problems before they become serious. If erosion is a problem at the water line, install riprap. Do not allow weeds to grow along the water line and keep weeds on the levee mowed. If insect larvae are observed on the pond surface, spray with an appropriate insecticide before problems develop.

D. Observe and test pond condition.

Daily visual observations can reveal if a pond is treating the wastewater properly. The pond should be a deep green color indicating a healthy algae population. Scum and floating weeds should be removed to allow sunlight to reach the algae in the pond.

Once or twice a week tests should be conducted to determine pond dissolved oxygen level, pH and temperature. Effluent dissolved oxygen should be measured at this time also. Other effluent tests should be conducted at least weekly and include BOD, suspended solids, dissolved solids, coliform-group bacteria and chlorine residual. If ponds are operated on a batch or controlled discharge basis, these effluent tests will have to be determined only during periods of discharge.

During warm summer months algae populations tend to be high and may cause high suspended solids concentrations in the effluent. An advantage of ponds in arid regions is that this is also a period of high evaporation rates. Under these conditions effluent flows may drop to almost zero or may be stopped. In the fall and winter when the weather is cool and sunlight is reduced, the algae population in ponds and thus the suspended solids are reduced. This situation could allow ponds to meet effluent requirements during this period.

If test results reveal that certain water quality indicators (such as DO, BOD, pH or suspended solids) are tending to move in the wrong direction, try to identify the cause and take corrective action. Remember that ponds are a biological process and that changes resulting from corrective action may not occur until a week or so after changes were made.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 313.

9.7I Why are the contents of ponds recirculated?

9.7J When do ponds that are operated on a batch basis discharge?

9.7K What factors would you consider when developing an operating strategy for ponds?

9.8 SURFACE AERATORS (Figs. 9.5 and 9.6 and Table 9.2)

Surface aerators have been used in two types of applications:

1. To provide additional air for ponds during the night, during cold weather, or for overloaded ponds; and
2. To provide a mechanical aeration device for ponds operated as an aerated lagoon. Aerated lagoons operate like activated sludge aeration tanks without returning any settled activated sludge.

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[12] *Stop Log. A log or board in an outlet box or device used to control the water level in ponds.*

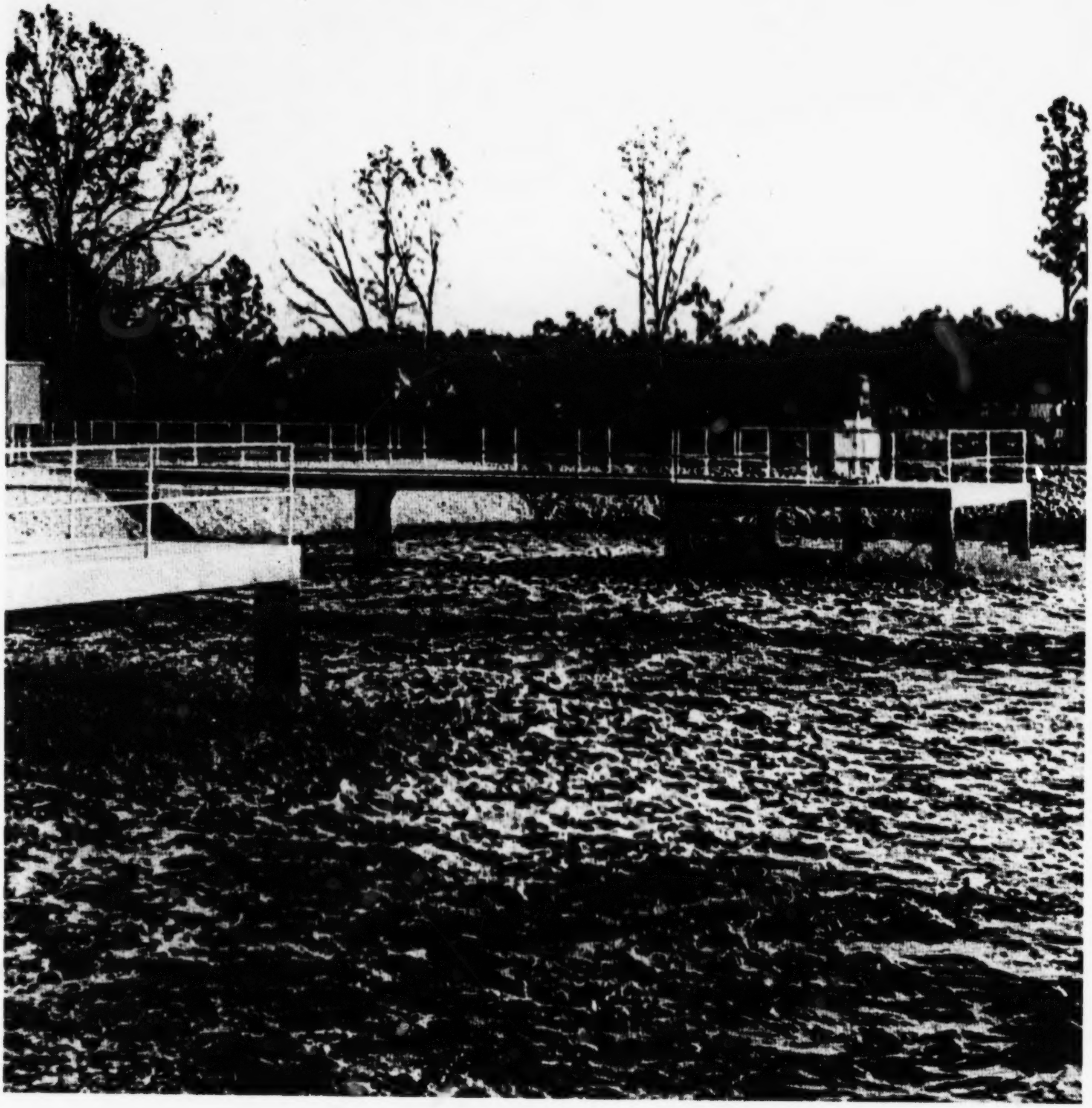


Fig. 9.5 Surface aerator

(Permission of EIMCO)

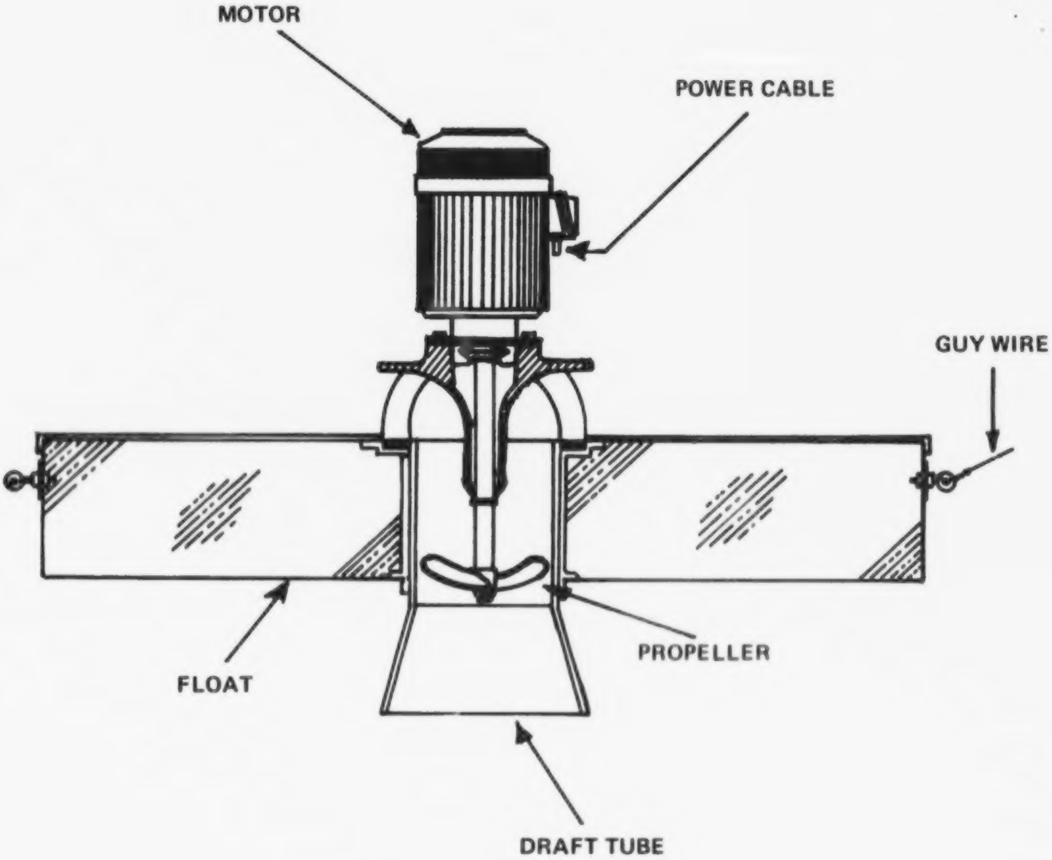

MOTOR
POWER CABLE
GUY WIRE
FLOAT
PROPELLER
DRAFT TUBE

Fig. 9.6 Floating surface aerator
(Permission of Aqua-Jet)

TABLE 9.2 PURPOSE OF AERATOR PARTS

Part	Purpose
1. Aerator	Introduces oxygen into pond.
2. Electric Motor	Provides energy to drive aerator.
3. Drive Reduction Gear Box	Converts torque from motor to move aerator.
4. Draft Tube	Conveys bottom contents of pond to surface for aeration.
5. Discharge Guide	Regulates spray patterns for oxygen transfer to water.
6. Jacking Screw	Adjusts aerator impeller level in water to regulate oxygen transfer.
FLOATING AERATOR COMPONENTS (additional)	
7. Pontoons or Floats	Provide platform for motor.
8. Guy Wires	Positions floats in ponds and are anchored to pond levee.
9. Power Cable	Conveys power to motor.
10. Propeller (aerator)	Pumps water into air to be aerated.

In both cases, the aerators are operated by time clocks with established on-off cycles. Laboratory tests on the dissolved oxygen in a pond indicate the time period for on and off cycles to maintain aerobic conditions in the surface layers of the pond. Adjustments in the on-off cycles are necessary when changes occur in the quantity and quality of the influent and seasonal weather conditions. Some experienced operators have correlated their lab test results to pond appearance and regulate the on-off cycles using the following rule: "If the pond has foam on the surface, reduce the operating time of the aerator; and if there is no evidence of foam on the pond surface, increase the operating time of the aerator." If there is a trace of foam on the surface, the operating time is satisfactory.

Surface aerators may be either stationary or floating. Maintenance of surface aerators should be conducted in accordance with manufacturer's recommendations. Always turn off, tag, and lock out electric current when repairing surface aerators. Special precautions may be necessary to handle problems with icing and winter maintenance. Overhead guy wires have been used to prevent aerators from turning over when iced up.

Another method of aerating ponds is by the use of air compressors connected to plastic tubes placed across the pond bottom. Holes are drilled in the plastic tubes which serve as diffusers to disperse air in the pond. This method of aeration requires less equipment maintenance than surface aerators, but diffusers can become plugged and create maintenance problems.

Aeration tubing requires an effective maintenance program. The type of maintenance depends on the type of aeration system and problems encountered.

1. Gas cleaning. Some aeration tubing systems require cleaning on a weekly basis with anhydrous hydrogen chloride gas. The gas removes deposits on the tubing slits and destroys biological slime that may grow in the tubing. The deposits are caused by the precipitation of carbonate and bicarbonate compounds.

   Anhydrous hydrogen chloride gas is extremely dangerous. Be cautious when using it. If you have gas connections on the lagoon embankment, be sure to stand upwind from the HCl tank. In systems using central manifolds, you must be cautious of HCl gas accumulating in low areas (HCl gas is heavier than air). Also, the monel needle must be closed prior to opening the cylinder valve. Two gas manifolds have ruptured in Vermont due to excess pressures in the manifolds as a result of the monel needle being open too far. Begin at the last header in the lagoon and work your way forward. Apply the gas from one side with the opposite header shut off and then reverse the procedure.
2. High pressure air purging. Some aerated lagoon facilities are capable of applying 90 psi (620 kPa) of compressed air to the system just after the blowers and the air manifold. The air manifold values and blowers should be off. This is not the pressure which will reach the lagoon tubing because of the friction losses in the tubing system. High pressure cleaning will greatly deform the slit in the tubing and break off deposits farther back in the tubing. High pressure air may be applied for three to five minutes once a year.
3. Slit deformation. The aeration tubing slits may be allowed to deform by shutting off the air once a day for about 20 minutes. The weight of the water above the tubing will cause the slits to be deformed inward, thus breaking up the deposits.
4. Removal of tubing and cleaning. A very thorough but time consuming job is the drawdown of the lagoon and removal of the tubing for cleaning. The tubing can be flexed by hand or with special equipment to break up deposits and the inner surfaces of the tubing may be blown out with high pressure air. You may avoid draining the lagoon to clean the tubing by using a boat, retrieving one end of a line of tubing, and manually flexing each section of tubing.
5. Blowouts. Blowouts of aeration tubing and boils caused by slit enlargements must be repaired. The damaged area must be cut out and a special coupling inserted and clamped in place. The lagoon water level may have to be lowered so the line can be hooked and drawn to the surface for repair.
6. Acknowledgment. Material in this section was provided by Jon Jewett.

9.9 SAMPLING AND ANALYSIS

9.90 Importance

Probably the most important sampling that can be accomplished easily by any operator is routine pH and dissolved oxygen analysis. A good practice is to take pH, temperature, and dissolved oxygen tests several times a week, and occasionally during the night. These values should be recorded because they will serve as a valuable record of performance. The time of day should be varied occasionally for the tests so that the operator becomes familiar with the pond's characteristics at various times of the day. Usually the pH and dissolved oxygen will be lowest just at sunrise. Both will get progressively higher as the day goes on, reaching their highest level in late afternoon.

Be very careful to avoid getting any atmospheric oxygen into the sample taken to measure dissolved oxygen. This is most necessary when samples are taken in the early morning or if the dissolved oxygen in the pond is low from overloading. If possible, measure the dissolved oxygen with an electric meter and probe, being careful not to allow the membrane on the end of the probe to be exposed to the atmosphere during actual DO measurement of the water sample.

Ponds often have clearly developed individuality, each being a biological community that is unique unto itself. Apparently identical adjacent ponds receiving the same influent in the same amount often have a different pH and a different dissolved oxygen content at any given time. One pond may generate considerable scum while its neighbor doesn't have any scum. For this reason, *EACH* pond should be given routine pH and dissolved oxygen tests. Such testing may indicate an unequal loading because of the internal clogging of influent or distribution lines that might not be apparent from visual inspection. Tests also may indicate differences or problems that are being created by a build-up of solids or solids recycling.

When an operator becomes familiar with operating a pond, the results of some of the chemical tests can be related to visual observations. A deep green sparkling color generally indicates a high pH and a satisfactory dissolved oxygen content. A dull green color or lack of color generally indicates a declining pH and a lowered dissolved oxygen content. A grey color indicates the pond is being overloaded or not working properly.

9.91 Frequency and Location of Lab Samples

The frequency of testing and expected ranges of test results vary considerably from pond to pond, but you should establish those ranges within which your pond functions properly. Test results will also vary during the hours of the day. Table 9.3 summarizes the typical tests, locations, and frequency of sampling.

Samples should always be collected from the same point or location. Raw wastewater samples for pond influent tests may be collected either at the wet well of the influent pump station or at the inlet control structure. Samples of pond effluent should be collected from the outlet control structure or from a well-mixed point in the outfall channel. Pond samples may be taken from the four corners of the pond. The samples should be collected from a point eight feet (2.5 m) out from the water's edge and one foot (0.3 m) below the water surface. Be careful; try not to stir up material from the pond bottom. Do not collect pond samples during or immediately after high winds or storms because solids will be stirred up after such activity.

TABLE 9.3 FREQUENCY AND LOCATION OF LAB SAMPLES

Test	Frequency[d]	Location	Common Range
pH[a]	Weekly	Pond	7.5+
Dissolved Oxygen (DO)[a]	Weekly	Pond	4 - 12 mg/*L*
		Effluent	4 - 12 mg/*L*
Temperature	Weekly	Pond	
BOD[b]	Weekly	Influent	100 - 300 mg/*L*
		Effluent	20 - 50 mg/*L*
Coliform Group Bacteria	Weekly	Effluent	MPN > 24,000/100 m*L* (unchlorinated)
Chlorine Residual	Daily	Effluent	0.5 - 2.0 mg/*L*
Suspended Solids[c]	Weekly	Influent	100 - 350 mg/*L*
		Effluent	40 - 80 mg/*L*
Dissolved Solids	Weekly	Influent	250 - 800 mg/*L*

[a] pH values above 9.0 and DO levels over 15 mg/*L* are not uncommon.

[b] Contact your regulatory agency to determine whether effluent samples should be filtered to remove algae before testing. If the samples must be filtered, the agency will recommend the proper procedures.

[c] Effluent suspended solids consist of algae, microorganisms and other suspended matter.

[d] Tests may be less frequent for ponds with long detention times (greater than 100 days).

BOD should be measured on a weekly basis. Samples should be taken during the day at low flow, medium flow, and high flow. The average of these three tests will give a reasonable indication of the organic load of the wastewater being treated. If it is suspected that the BOD varies sharply during the day or from day to day, or if unusual circumstances exist, the sampling frequency should be increased to obtain a clear definition of the variations. If the pond DO level is supersaturated (see Chapter 16, section on DO tests), the sample must be aerated to remove the excess oxygen before the BOD test is performed. A typical data sheet for a plant consisting mainly of ponds is provided in the Appendix at the end of this chapter. Figure 9.7 shows the influent and effluent BOD and suspended solids values from an actual pond.

A *GRAB SAMPLE*[13] is a single sample. Grab samples are used to measure temperature, pH, dissolved oxygen and chlorine residual. These tests must be performed immediately after the sample is collected in order to obtain accurate results. *COMPOSITE SAMPLES*[14] of pond influent or effluent are collected by gathering individual samples at regular intervals over a selected period of time. The individual samples are then mixed together proportionally to the flow at the time of sampling. Pond samples may be composited by mixing equal portions from the four corners of the pond. Composite samples should be placed in a refrigerator or ice box as soon as possible after they are collected. BOD and suspended solids are measured using composite samples.

Tests of pH, DO, and temperature are important indicators of the condition of the pond, whereas BOD, coliform, and solids tests measure the efficiency of the pond in treating wastes. BOD is also used to calculate the loading on the pond.

In order to estimate the organic loading on the pond, the operator must have some knowledge of the biochemical oxygen demand (BOD) of the waste and the approximate average daily flow. Influent BOD and solids will vary with time of day, day of week, and season, but a pond is a good equalizer if not overloaded.

Tests for pond alkalinity can provide helpful information to an operator. After you have determined "normal" alkalinity levels for your pond, a sudden change in alkalinity of 10 to 20 mg/*L* or more may indicate that a problem is developing. A change in alkalinity may be a warning that the pH of the pond could change in a day or two if corrective action is not taken. If a trend in changes in alkalinity continues in one direction for two or three days, the cause of this change should be identified. For useful results, the alkalinity test should be performed every day.

9.92 Expected Treatment Efficiencies[15]

Table 9.4 is provided as a guide to indicate probable removal efficiencies of typical ponds.

---

[13] *Grab Sample. A single sample taken at neither a set time nor flow.*

[14] *Composite (Proportional) Sample (com-POZ-it). A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.*

[15]

$$\text{Waste Removal, \%} = \frac{\text{(In - Out)}}{\text{In}} \times 100\% \quad \text{See page 299 for example.}$$

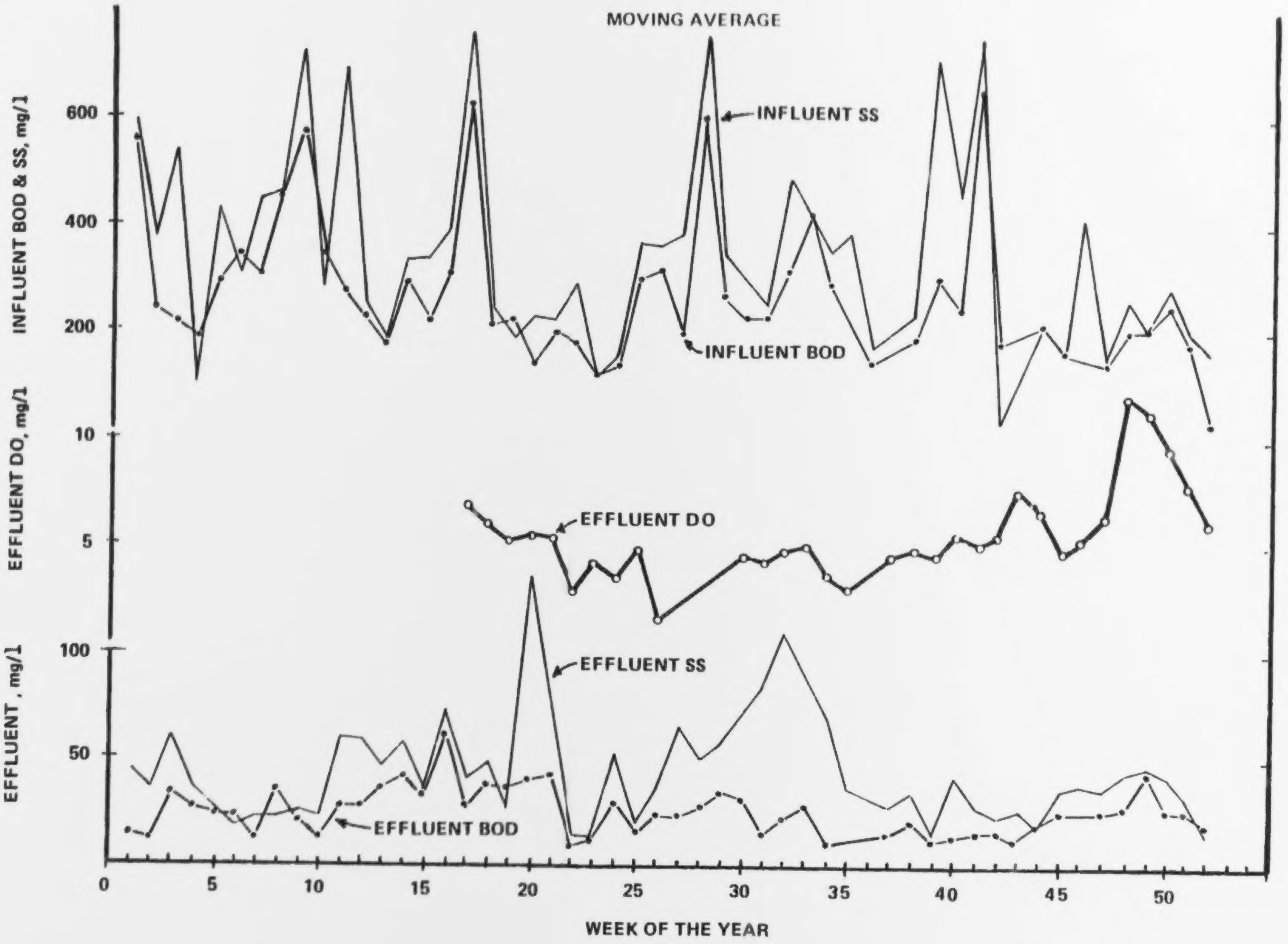


Fig. 9.7 Pond influent and effluent BOD and suspended solids values

TABLE 9.4 EXPECTED RANGES OF REMOVAL BY PONDS

	Detention Time	Expected Removal[15]
BOD		50 to 90%
BOD (*FACULTATIVE POND*)[16]	50 to 60 days	70 to 80%[17]
Coliform Bacteria (facultative pond)	50 to 60 days	90 to 95%
Suspended Solids	After 3 days	90%
Dissolved Organic Solids	After 10 days	80%

The calculation of pond BOD removal efficiency is figured in terms of the percentage of BOD removed.

Example:

The influent BOD to a series of ponds is 300 mg/*L*, and the effluent BOD is 60 mg/*L*. What is the efficiency of BOD removal?

$$\begin{aligned}\text{BOD Removal, \%} &= \frac{(\text{In} - \text{Out})}{\text{In}} \times 100\% \\ &= \frac{(300 \text{ mg}/L - 60 \text{ mg}/L)}{300 \text{ mg}/L} \times 100\% \\ &= \frac{240 \text{ mg}/L}{300 \text{ mg}/L} \times 100\% \\ &= 0.80 \times 100\% \\ &= 80\%\end{aligned}$$

9.93 Response to Poor Pond Performance

See Section 9.7, "Daily Operation and Maintenance," especially 9.75, "Some Operating Hints."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 313.

9.8A Surface aerators have been used in what two types of applications?

9.9A If the color of a pond is dull green or colorless, what is happening in the pond?

9.9B Why should the pH, temperature, and dissolved oxygen be measured in a pond?

9.9C If the pH and dissolved oxygen are dropping dangerously low in a pond, how can this situation be corrected?

9.9D Influent BOD to a series of ponds is 200 mg/*L*. If the BOD in the effluent of the last pond is 40 mg/*L*, what is the BOD removal efficiency?

9.10 SAFETY

Even though a pond has little mechanical equipment, there still are hazards. Catwalks should have guardrails and non-skid walking surfaces. Headworks and any enclosed appurtenances should be well ventilated to prevent dangerous gas accumulations.

WARNING

AN OPERATOR SHOULD **ALWAYS** BE ACCOMPANIED BY A HELPER WHEN PERFORMING ANY TASK THAT IS **DANGEROUS** SINCE POND LOCATIONS ARE USUALLY QUITE ISOLATED.

Be very careful when removing debris from channels and ponds. Do not attempt to lift too much. Make certain you have secure footing so you won't slip and fall. Never stand in a boat or lean over too far to one side, for you could fall into the pond and also possibly tip over the boat. Always wear a life jacket when in a boat.

Electrical wires and electrical equipment are always a source of potential danger. Exercise caution when cutting weeds or removing vegetation such as trees next to electrical wires. Electrical wires in damp areas can be dangerous. Be careful when spraying weeds around electrical wires and equipment because the spray could act as a conductor. Always turn off, tag, and lock out electric current when repairing surface aerators and other equipment operated by electricity.

When applying pesticides or herbicides, be sure they are approved by the appropriate officials for your specific use and *FOLLOW THE DIRECTIONS EXACTLY*. This includes following the directions for using the proper mixing or preparing the solution, applying the solution, disposing of any excess solution and the containers, and cleaning up before you go home. Not only can you kill the target pest or weed, but carelessness can harm nearby grasses, plants, trees, fishes, birds and even people, including yourself. Also failure to follow directions may result in harm to the algae and microorganisms in the pond.

Tetanus and typhoid are ever-present dangers when working around wastewater. Adequate precautions should be observed by cleaning all cuts and scrapes and always washing before eating or smoking.

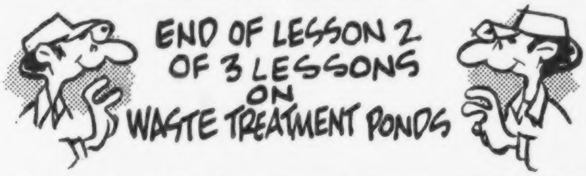
Fences should surround ponds to keep unauthorized persons and animals out of the pond area. They should be located in such a manner that they will not interfere with mechanical or hand maintenance of levee slopes.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 313.

9.10A What safety devices should be provided on catwalks over ponds?

9.10B Why should an operator be accompanied by a helper when performing any dangerous task?



Please answer the discussion and review questions before continuing with Lesson 3.

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[16] *Facultative Pond (FACK-ul-tay-tive). The most common type of pond in current use. The upper portion (supernatant) is aerobic while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.*

[17] *Expected removal approximately 80 percent of the time with poorer removals during the remainder of the time.*

DISCUSSION AND REVIEW QUESTIONS

Chapter 9. WASTE TREATMENT PONDS

(Lesson 2 of 3 Lessons)

Write your answers in a notebook. The problem numbering continues from Lesson 1.

6. Why should water be introduced into a new pond before any wastewater?
7. Why is good housekeeping an important factor in operating a properly functioning pond?
8. What precautions should be taken when applying an insecticide?
9. Why may chlorine compounds or chlorine solution not be the best method of odor control in a pond?
10. What lab tests measure the condition of a pond?
11. Estimate the BOD removal efficiency of a series of ponds if the influent BOD is 250 mg/*L* and the effluent BOD is 50 mg/*L*.
12. Why should fences be placed around ponds?

CHAPTER 9. WASTE TREATMENT PONDS

(Lesson 3 of 3 Lessons)

9.11 REVIEW OF PLANS AND SPECIFICATIONS

A careful review of the plans and specifications of a proposed pond can provide the operator an opportunity to suggest design improvements and changes before construction which will allow the operator and the ponds to do a better job. Guidelines for reviewing plans and specifications are provided in this section. If you are having trouble with an existing pond or ponds, check the items discussed in this section for help in locating possible sources of problems.

9.110 Location

The general considerations for the location of other types of wastewater treatment plants also apply to the location of ponds. Isolation should be as great as can be economically provided. Attention to the direction of prevailing winds with due regard for present and projected downwind residential, commercial, and recreational development is of utmost importance.

Winds can have both favorable and unfavorable impacts on ponds. Winds are desirable in terms of blowing surface scum and weeds to one side of the pond where they can be removed. Also winds can be helpful by mixing the contents of a pond, such as DO, algae and incoming wastes. An undesirable aspect of winds is the creation of waves which can erode the pond levee. Both of these factors should be considered when selecting the location of the ponds and the arrangement or length of the ponds. If high winds are to be expected in the area where ponds will be constructed, try to arrange the ponds so the winds will blow across the short width of the pond rather than the length in order to reduce levee erosion caused by waves.

9.111 Chemistry of Waste

Before the design of any pond is undertaken, it should be determined whether there are any *POSSIBLE TOXIC*[18] *EFFECTS* (interfere with growth of algae or bacteria) from the waste. Some natural water supplies may have a high sulfur content or other chemicals that limit the possibility of desired sludge decomposition.

Certain wastes, such as dairy products and wine products, are difficult to treat because of their low pH. Any processing waste must be carefully investigated before one can be certain that it can be successfully treated by ponding. Some process wastes contain powerful fungicides and disinfectants that may have a great inhibitive effect on the biological activity in a pond. Other wastes may have nutrient deficiencies that could inhibit the growth of desirable types of algae.

9.112 Headworks and Screening

A headworks with a bar screen is desirable to remove rags, bones, and other large objects that might lodge in pipes or control structures.

A trash shredder is a luxury that may not be warranted. Any material that gets past an adequate bar screen will, in all probability not harm the influent pump. Any fecal matter will be pulverized when going through the pump.

9.113 Flow-Measuring Devices

An influent-measuring device should be installed to give a direct reading on the daily volume of wastes that are introduced into the ponds. This information, along with a BOD measurement of the influent, is required to estimate the organic loading on the pond. Comparison of influent and effluent flow rates is necessary for estimating percolation and evaporation losses.

A measuring device provides basic data for prediction of future plant expansion needs or for detecting unauthorized or abnormal flows. Reliable, well-kept records on flow volume help justify budgets and greatly assist an engineer's design of a plant expansion or new installation.

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[18] *Toxic (TOX-ick). Poisonous.*

9.114 Inlet and Outlet Structures

Inlet structures should be simple, foolproof, and constructed of standard manufactured articles so that replacement parts are readily available. Telescoping friction-fit tubes (see Fig. 9.8) for regulating spill or discharge height should be avoided because a biological growth may become attached and prevent the tubes from telescoping if they are not cleaned regularly. Occasional dosages of hypochlorite solution can effectively discourage growths. Also the formation of ice can prevent adjustment of the tubes. If freezing is a problem, a polyethelyne floating ring around the friction tube of the telescopic valve sprayed with urea can prevent freeze-ups. This device will act as a floating baffle to keep scum and floating debris from clogging up the tube and entering the effluent.

Figure 9.1 (page 282) shows four inlets to one pond. With this type of installation, usually only one inlet valve is open at a time. If all the valves were open, velocities in the pipes might become too low and solids would settle out in the pipes. To overcome low velocities, close all but one valve or recycle pond effluent back to the inlet. When all inlet valves are open, the load is more evenly distributed throughout the pond.

A submerged inlet will minimize the occurrence of floating material and will help conserve the heat of the pond by introducing the warmer wastewater into the depths of the pond. Warm wastewater introduced at the bottom of a cold water mass will channel to the surface and spread unless it is promptly and vigorously mixed with cold water. Warm wastewater spilled onto the surface of the pond will spread out in a thin layer on the surface and not contribute to the warmth of the lower regions of the pond where heat is needed for bacterial decomposition. Inlet and outlet structures should be so located in relation to each other to minimize possible short-circuiting.

Outlet structures (Figs. 9.9 and 9.10) should consist of a baffled and submerged pipe inlet to prevent scum and other floating surface material from leaving the pond. The actual level of the pond and rate of outflow can be controlled by the use of flashboards in the outlet structure. A row boat may be used when access to the outlet baffle in Figure 9.9 is required.

Valves that have stems extending into the stream flow should be avoided. Stringy material and rags will collect, form an obstruction, and may render the valve inoperative.

Free overfalls (Fig. 9.11) at the outlet should be avoided to minimize release of odors, foaming, and gas entrapment which may hamper pipe flows. Free overfalls should be converted to submerged outfalls if they are causing nuisances and other problems.

If a pond has a surface outlet, floating material can be kept out of the effluent by building a simple baffle around the outlet. The baffle can be constructed of wood or other suitable material. This baffle should be securely supported or anchored.

9.115 Levees

The selection of the steepness of the levee slope must depend on several variables. A steep slope erodes quicker from wave wash unless the levee material is of a rocky nature or else protected by riprap. However, a steep slope minimizes waterline weed growth. Equipment operation and the performance of routine maintenance are more difficult on steep slopes. A gentle slope will erode the least from wave wash. Also, it is easier to operate equipment and easier to perform routine maintenance on a gentle slope. However, waterline weed growth will have a much greater opportunity to flourish.

Ensure that provisions are made to adequately compact and/or seal the levee banks to prevent leaking. Pipes passing through levees should be as close to horizontal as possible to reduce the possibility of leaks. Also cut-off walls should be installed when pipes pass through levees to prevent leakage around the outside of the pipes. Proper compaction and sealing is necessary around pipes, *SPLASH PADS,*[19] cleanouts, valves, inlet and outlet control structures, and also recirculation, transfer and drain lines. Once a leak develops, stopping it can be very difficult.

The top of the levee should be at least ten feet (3.1 m) wide to allow for maintenance vehicles. Provisions should be made for a rounded or sloping top to allow for drainage. Pave or gravel the levee surface if it will be used as a roadway during wet weather.

9.116 Pond Depths

The operational depth of ponds deserves considerable attention. Depending upon conditions, ponds of less than three feet (1 m) of depth may be completely aerobic if there are no solids on the bottom (unlikely) because of the depth of sunlight penetration. This means that the treatment of wastes is accomplished essentially by converting the wastes to algae cell material. Ponds of this shallow depth with short detention times are apt to be irregular in performance because algae blooms will increase to such proportions that a mass die-off will occur. When this happens, all algae sink to the bottom and thereby add to the organic load. Such conditions could lead to the creation of an anaerobic pond. The bottoms of shallow ponds will become anaerobic when solids collect on the bottom and after sunset.

Discharges from shallow, aerobic ponds contain large amounts of algae. To operate efficiently, these ponds should have some means of removing the algae grown in the pond before the effluent is discharged to the receiving waters. If the algae are not removed from the effluent, the organic matter in the wastewater is not removed or treated and the problem is merely transferred to some downstream pool. See Section 9.12, "Removal of Algae from Pond Effluents," for a discussion of possible methods of algae removal.

An observed phenomenon of lightly loaded, shallow secondary ponds and tertiary ponds is that they are apt to become infested with filamentous algae and mosses that not only limit the penetration of sunlight into the pond, but hamper circulation of the pond's contents and clog inlet and outlet structures. When the loading is increased, this condition improves because these algae and mosses require relatively clean water (low nutrients) for their environment.

Pond depths of four feet (1.2 m) or more allow a greater conservation of heat from the incoming wastes. This encourages biological activity as the ratio between pond volume and pond area is more favorable. In facultative ponds, depths over four feet (1.2 m) provide physical storage for dissolved oxygen accumulated during the day. The stored dissolved oxygen carries over through the night when no oxygen is released by the algae, unless floating algae and poor circulation keep all the oxygen near the surface. This physical storage of DO is very important during the colder months when nights are long.

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[19] *Splash Pad. A structure made of concrete or other durable material to protect bare soil from erosion by splashing or falling water.*

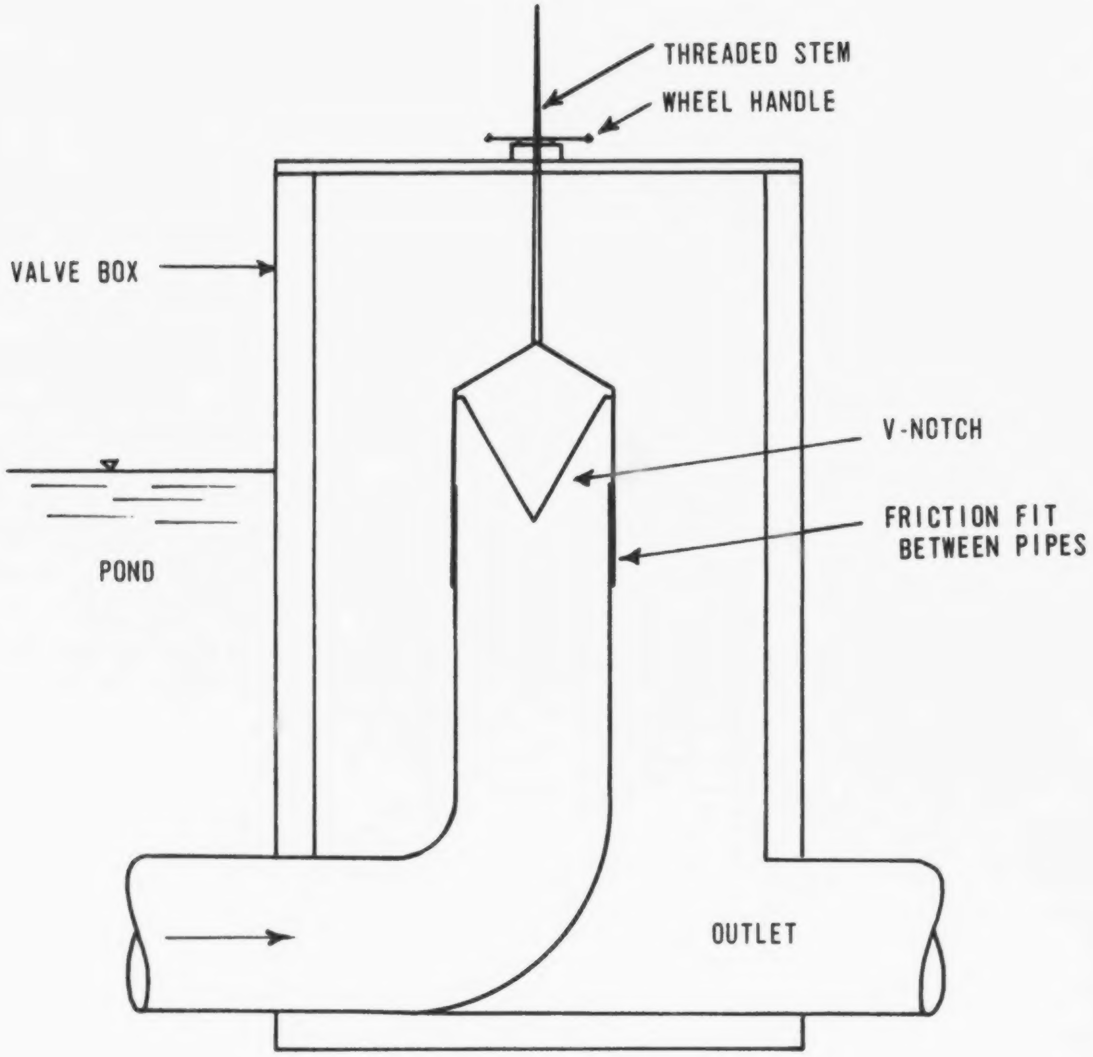

THREADED STEM
WHEEL HANDLE
VALVE BOX
V-NOTCH
FRICTION FIT BETWEEN PIPES
POND
OUTLET

Fig. 9.8 Telescoping friction-fit tubes for regulating discharge. These tubes must be exercised regularly to prevent becoming stuck.

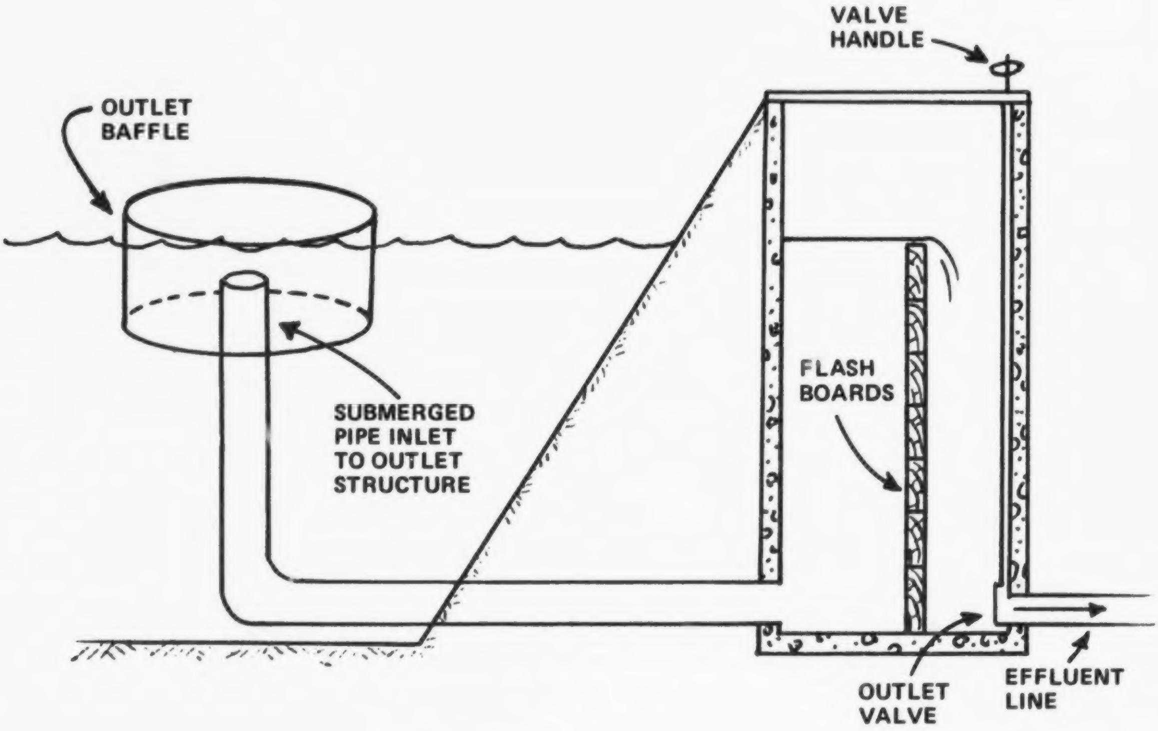

VALVE HANDLE
OUTLET BAFFLE
SUBMERGED PIPE INLET TO OUTLET STRUCTURE
FLASH BOARDS
OUTLET VALVE
EFFLUENT LINE

Fig. 9.9 Pond outlet structure

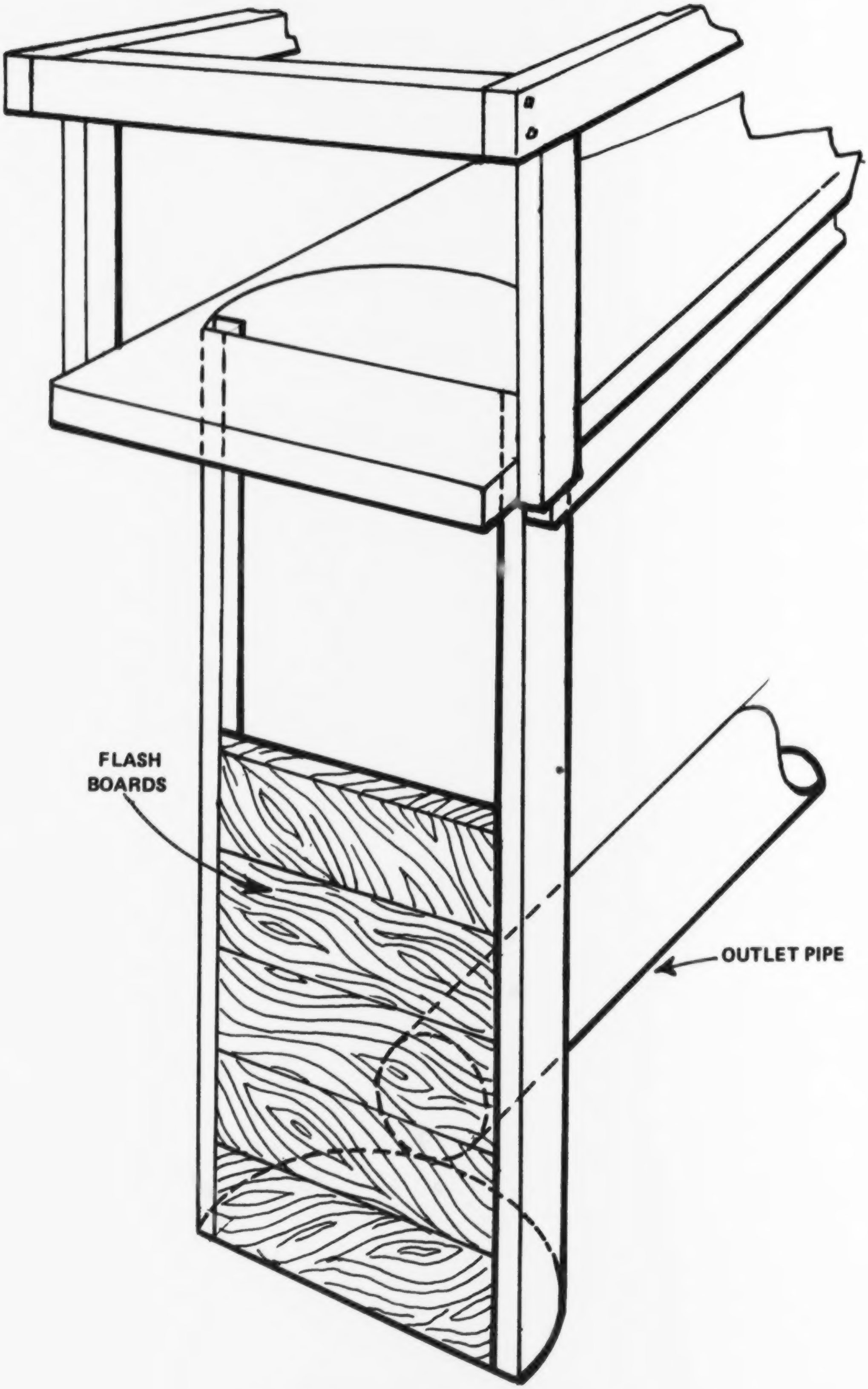
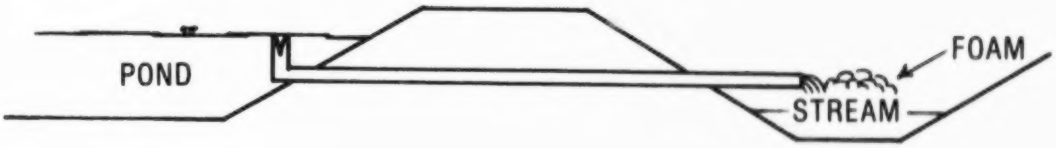
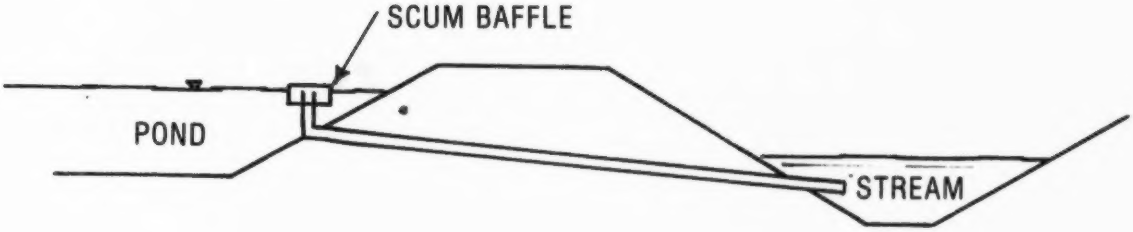

FLASH BOARDS
OUTLET PIPE

Fig. 9.10. Pond outlet control structure


POND
FOAM
STREAM

FREE OVERFALL -- UNDESIRABLE


SCUM BAFFLE
POND
STREAM

SUBMERGED OUTLET -- NO FOAMING PROBLEMS

Fig. 9.11 Free overfall and submerged outlet

A pond operating depth of at least three feet (1 m) is recommended to prevent tule and cattail growth. Weeds that emerge along the shore line can be effectively controlled by spraying with any of several products available. Ponds designed for depths less than three feet (1 m) should be lined to prevent troublesome weed growth.

9.117 Fencing and Signs

The pond area must be surrounded by a fence capable of keeping livestock out and discouraging trespassing. A gate wide enough to allow mowing equipment and other maintenance vehicles to enter the pond facility should be provided. All access gates should have locks.

Signs should be posted along the fence around the ponds to indicate the nature of the facility and to forbid trespassing. The signs should not be more than 300 feet apart.

9.118 Surface Aerators

Provisions must be made for easy access and sufficient space for maintenance and repair of fixed aerators. Alternate anchor points should be installed in order to move floating aerators. Also be sure the electrical cables are long enough to permit easy movement of the aerator and large enough to handle anticipated loads.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 313.

9.11A Why are some wastes not easily treated by ponds?

9.11B What is the minimum recommended pond operating depth?

9.11C Why should the inlet to a pond be submerged?

9.11D Why should the outlet be submerged?

9.11E How could problems created by a surface outlet be reduced or corrected?

9.11F Why should free overfalls be avoided?

9.11G Why are shallow ponds apt to be irregular in performance?

9.11H Why should the influent to a pond be metered?

9.119 Pond Loading (English and Metric Calculations)

The waste loading on a pond is generally spoken of in relation to its area, and may be stated in several different ways:

1. lbs of BOD per day per acre = lbs BOD/day/acre (This is called "organic loading.");
2. inches (or feet) of depth added per day (This is called "hydraulic loading" or "overflow rate."); or
3. persons (or population served) per acre (This is called "population loading.").

Detention time is related directly to pond hydraulic loading, which is actually the rate of inflow of wastewater. It may be expressed as million gallons per day (MGD), or as the number of acre-inches per day or acre-feet per day (one acre-foot covers one acre to a depth of one foot or twelve inches and is equal to 43,560 cu ft). We must know the pond volume in order to determine detention time; this is most easily computed on an acre-foot basis.

A. Detention Time

$$\text{Detention (in days)} = \frac{\text{Pond Volume (ac-ft)}}{\text{Influent Rate (ac-ft/day)}}$$

This equation does not take into consideration water which may be lost through evaporation or percolation. Detention time may vary from 30 to 120 days, depending on the treatment requirements to be met. Controlled discharge ponds may have minimum detention times of 180 days. Ponds whose discharges are disposed of by land application may have 210-day minimum detention times.

B. Population Loading

Loading calculated on a population-served basis is expressed simply as:

$$\text{No. of Persons per Acre} = \frac{\text{Population Served, persons}}{\text{Area of Pond, ac}}$$

The population loading may vary from 50 to 500 persons per acre, depending on many local factors.

C. Hydraulic Loading

The hydraulic loading or overflow rate is expressed as:

$$\text{Inches per day} = \frac{\text{Inflow (ac-in per day)}}{\text{Pond Area, ac}}$$

The hydraulic loading may vary from half an inch to several inches per day, depending on the organic load of the influent.

NOTE: If the wastewater inflow rate is known in million gallons per day (MGD), it can be converted to an equivalent number of acre-inches per day as follows:

$$\text{Inflow, acre-inches per day} = (\text{Inflow, MGD}) \times 36.8^{20}$$

If the pond detention time is known, the hydraulic loading can also be calculated, as follows:

$$\text{Inches per day} = \frac{\text{Depth of Pond, in}}{\text{Detention Time, days}}$$

D. Organic Loading

The organic loading is expressed as:

$$\begin{array}{l}\text{Organic Load}\\ \text{(lbs BOD per}\\ \text{day per acre)}\end{array} = \frac{(\text{BOD, mg/L})\ (\text{Flow, MGD})\ (8.34\ \text{lbs/gal})^{21}}{\text{Pond area, ac}}$$

Typical organic loadings may range from 10 to 50 lbs BOD per day per acre. Recirculation will help an overloaded pond.

---

[20] $1\ MGD = \frac{1{,}000{,}000\ gal}{day} \times \frac{1\ cu\ ft}{7.48\ gal} \times \frac{1\ ac}{43{,}560\ sq\ ft} \times \frac{12\ in}{1\ ft} = 36.8\ \frac{ac\text{-}in}{day}$

[21] *Recall lbs/day = (Conc. mg/M mg) (M gal/day) (8.34 lbs/gal)*

EXAMPLE CALCULATIONS

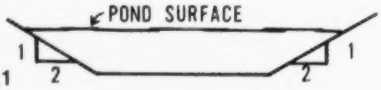
NOTE TO OPERATOR: If you have difficulty following the work shown in Example 1 below, you should refer to Section 9.16, "Pond Attachment," at the end of this chapter for further details. If you have no trouble, continue with the lesson.

EXAMPLE NO. 1:

Use of the pond loading formulas can be illustrated by examining a typical situation. The following data should be obtained so that all the calculations can be performed:

Essential Data

1. Depth of Pond = 4 feet
2. Width of Pond
   - Bottom = 412 feet
   - Water Surface = 428 feet
   - Average Width = 420 feet
3. Length of Pond
   - Bottom = 667 feet
   - Water Surface = 683 feet
   - Average Length = 675 feet
4. Side Slopes (2 ft horizontal to 1 ft vertical) = 2:1



5. Influent Flow = 0.2 million gallons per day
   - = 0.2 MGD
   - = 200,000 gallons per day
6. Influent BOD = 200 mg/*L*
   - = 200 lbs BOD per million lbs of wastewater
7. Population = 2000 persons

To calculate the loading criteria, first determine the pond area and volume.

I. POND AREA, ACRES

$$\text{Pond Area, ac} = \frac{(\text{Average Width, ft})(\text{Average Length, ft})}{43{,}560 \text{ sq ft/ac}}$$

$$= \frac{(420 \text{ ft})(675 \text{ ft})}{43{,}560 \text{ sq ft/ac}}$$

$$= 6.51 \text{ ac}$$

II. POND VOLUME, ACRE-FEET

$$\text{Volume, ac-ft} = (\text{Area, ac})(\text{Depth, ft})$$

$$= (6.51 \text{ ac})(4 \text{ ft})$$

$$= 26.04 \text{ ac-ft (say 26 ac-ft)}$$

Convert flow rate from gallons per day to ac-ft/day.

$$\text{Flow Rate, ac-ft/day} = \frac{200{,}000 \text{ gal}}{\text{day}} \times \frac{\text{cu ft}}{7.48 \text{ gal}} \times \frac{\text{ac}}{43{,}560 \text{ sq ft}}$$

$$= 0.61 \text{ ac-ft/day}$$

III. LOADING CRITERIA

NOTE TO OPERATORS: Details for calculations in the remainder of Example 1 have not been given. If you have trouble, go to the end of this lesson and study Section 9.16, "Pond Attachment," for details, and try to apply them to this section.

1. *DETENTION TIME*

$$\text{Detention Time, days} = \frac{\text{Pond Volume, ac-ft}}{\text{Flow Rate, ac ft/day}}$$

$$= \frac{26 \text{ ac-ft}}{0.61 \text{ ac-ft/day}}$$

$$= 42.6 \text{ days}$$

2. *POPULATION LOADING*

$$\text{Number of Persons per acre} = \frac{\text{Population Served by Sewer System, persons}}{\text{Pond Area, ac}}$$

$$= \frac{2000 \text{ Persons}}{6.51 \text{ ac}}$$

$$= 307 \text{ persons/ac}$$

NOTE: If there is a significant waste flow from industry mixed in with the domestic waste, an adjustment must be made to take the industrial waste into consideration. This is usually done by analyzing the industrial waste and converting it to a *POPULATION EQUIVALENT*.[22]

3. *HYDRAULIC LOADING (OVERFLOW RATE)*

$$\text{Inches per day} = \frac{\text{Depth of Pond, in}}{\text{Detention Time, days}}$$

$$= \frac{(\text{Depth, 4 ft})(12 \text{ in/ft})}{42.6 \text{ days}}$$

$$= 1.13 \text{ in/day}$$

4. *ORGANIC LOADING*

$$\text{Organic Load, lb BOD/day/ac} = \frac{(\text{BOD, mg}/L)(\text{Flow, MGD})(8.34 \text{ lb/gal})}{\text{Area, ac}}$$

$$= \frac{200 \text{ lb}}{\text{M lb}} \times \frac{0.2 \text{ M gal}}{\text{day}} \times \frac{8.34 \text{ lb}}{\text{gal}} \times \frac{1}{6.5 \text{ ac}}$$

$$= 51 \text{ lbs BOD/day/ac}$$

EXAMPLE NO. 2

NOTE TO OPERATORS: Details for calculations in Example 2 have not been given. If you have trouble, go back and study

---

[22] *Population Equivalent. A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pounds of oxygen per day for each person using the system (as measured by the standard BOD test).*

$$\text{Pop. Equiv., persons} = \frac{\text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34 \text{ lbs/gal}}{0.2 \text{ lbs BOD/day/person}}$$

the procedures for Example 1 and try to apply them to Example 2.

Suppose that a small wastewater treatment plant must be completely shut down for major repairs that will require several months of work. Enough vacant land is near the plant to enable 16 acres of temporary ponds to be constructed as raw wastewater (sewage) lagoons. Determine if this is feasible, given the following data:

Influent Rate = 1 MGD

Influent BOD = 150 mg/*L*
= 150 lbs BOD per million lbs of wastewater

Pond Area = 16 acres

Average Operating Depth = 42 inches = $\frac{42 \text{ in}}{12 \text{ in/ft}}$ = 3.5 ft

Assume that at least a 60-day detention period (average time the wastewater must take to flow through the pond for disinfection) is desired for bacterial die-off.

Assume that the organic loading (BOD) should not exceed 50 lbs per day per acre.

Calculate what the *WASTE DETENTION TIME* would be in the pond:

One acre-foot = 325,829 gallons

Pond Volume, ac-ft = Pond Area, ac × Pond Depth, ft
= 16 ac × 3.5 ft
= 56 ac-ft

Influent Flow Rate = 1,000,000 gals per day
= $\frac{1{,}000{,}000 \text{ gpd}}{325{,}829 \text{ gal/ac-ft}}$
= 3.07 ac-ft per day

Detention Time = $\frac{56 \text{ ac-ft}}{3.07 \text{ ac-ft per day}}$
= 18.2 days

Thus the detention time would not be sufficient to satisfy requirements. Increasing the depth to 5 feet would help.

Calculate the organic loading:

Organic Loading, lbs BOD/day = (BOD, mg/*L*) (Flow, MGD) (8.34 lbs/gal)
= (150 mg/*L*) (1 MGD) (8.34 lbs/gal)
= 1250 lbs BOD per day

The organic loading per acre of pond would be:

Organic Loading, lbs BOD/day/ac = $\frac{\text{Loading, lbs BOD/day}}{\text{Area, ac}}$
= $\frac{1250 \text{ lbs BOD per day}}{16 \text{ ac}}$
= 78.1 lbs BOD/day/ac

Therefore, the organic loading would exceed the desired maximum of 50 lbs BOD/day/acre.

QUESTION

Write your answers in a notebook and then compare your answers with those on pages 313 and 314.

9.111 Given a pond receiving a flow of 2.0 MGD from 20,000 people. Influent BOD is 180 mg/*L*. Pond area is 24 acres, and the average operating depth is four feet. Determine the detention time, organic loading, population loading, and hydraulic loading.

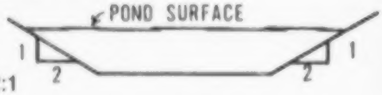
EXAMPLE METRIC CALCULATIONS

EXAMPLE NO. 1

Use of the pond loading formulas can be illustrated by examining a typical situation. The following data should be obtained so that all calculations can be performed:

Essential Data

1. Depth of Pond = 2.0 meters
2. Width of Pond
   Bottom = 125 meters
   Water Surface = 133 meters
   Average Width = 129 meters
3. Length of Pond
   Bottom = 200 meters
   Water Surface = 208 meters
   Average Length = 204 meters
4. Side Slopes
   (2 ft horizontal to 1 ft vertical) = 2:1



5. Influent Flow = 800 cubic meters per day
6. Influent BOD = 200 mg/*L*
7. Population = 2000 persons

To calculate the loading criteria, first determine the pond area and volume.

I. POND AREA, SQUARE METERS

Pond Area, sq m = (Average Width, m) (Average Length, m)
= (129 m) (204 m)
= 26,316 sq m

II. POND VOLUME, CUBIC METERS

Volume, cu m = (Area, sq m) (Depth, m)
= (26,316 sq m) (2 m)
= 52,632 cu m

III. LOADING CRITERIA

1. *DETENTION TIME*

$$\text{Detention Time, days} = \frac{\text{Pond Volume, cu m}}{\text{Flow Rate, cu m/day}}$$

$$= \frac{52{,}632 \text{ cu m}}{800 \text{ cu m/day}}$$

$$= 66 \text{ days}$$

2. *POPULATION LOADING*

$$\text{Number of Persons per square meter} = \frac{\text{Population Served by Sewer System, persons}}{\text{Pond Area, sq m}}$$

$$= \frac{2000 \text{ persons}}{26{,}316 \text{ sq m}}$$

$$= .076 \text{ persons/sq m}$$

NOTE: If there is a significant waste flow from industry mixed in with the domestic waste, an adjustment must be made to take the industrial waste into consideration. This is usually done by analyzing the industrial waste and converting it to a population equivalent.

3. *HYDRAULIC LOADING (OVERFLOW RATE)*

$$\text{Centimeters per day} = \frac{\text{Depth of Pond, cm}}{\text{Detention Time, days}}$$

$$= \frac{(\text{Depth, 2 m})\ (100 \text{ cm/m})}{66 \text{ days}}$$

$$= 3.03 \text{ cm/day}$$

4. *ORGANIC LOADING*

$$\text{Organic Load, gm BOD/Day/sq m} = \frac{(\text{BOD, mg}/L)\ (\text{Flow, cu m/day})\ (1 \text{ gm}/1000 \text{ mg})\ (1000\ L/\text{cu m})}{\text{Area, sq m}}$$

$$= \frac{200 \text{ mg}/L \times 800 \text{ cu m/day} \times 1 \text{ gm}/1000 \text{ mg} \times 1000\ L/\text{cu m}}{26{,}316 \text{ sq m}}$$

$$= 6.1 \text{ gm BOD/day/sq m}$$

EXAMPLE NO. 2:

Suppose that a small wastewater treatment plant must be completely shut down for major repairs that will require several months of work. Enough vacant land is near the plant to enable 65,000 square meters of temporary ponds to be constructed as raw wastewater (sewage) lagoons. Determine if this is feasible, given the following data:

Influent Rate = 4,000 cu m/day
Influent BOD = 150 mg/*L*
Pond Area = 65,000 square meters
Average Operating Depth = 1.2 meters

Assume that at least a 60-day detention period (average time the wastewater must take to flow through the pond for disinfection) is desired for bacterial die-off.

Assume that the organic loading (BOD) should not exceed 5 grams per day per square meter.

Calculate what the *WASTE DETENTION TIME* would be in the pond.

$$\text{Pond Volume, cu m} = \text{Pond Area, sq m} \times \text{Pond Depth, m}$$

$$= 65{,}000 \text{ sq m} \times 1.2 \text{ m}$$

$$= 78{,}000 \text{ cu m}$$

Influent Flow Rate = 4,000 cu m/day

$$\text{Detention Time, days} = \frac{\text{Pond Volume, cu m}}{\text{Influent Flow, cu m/day}}$$

$$= \frac{78{,}000 \text{ cu m}}{4{,}000 \text{ cu m/day}}$$

$$= 19.5 \text{ days}$$

Thus the detention time would not be sufficient to satisfy requirements. Increasing the depth to 3.5 meters would help.

Calculate the organic loading:

$$\text{Organic Loading, gm BOD/day} = (\text{BOD, mg}/L)\ (\text{Flow, cu m/day})\ (1 \text{ gm}/1000 \text{ mg})\ (1000\ L/\text{cu m})$$

$$= (150 \text{ mg}/L)\ (4000 \text{ cu m/day})\ (1 \text{ gm}/1000 \text{ mg})\ (1000\ L/\text{cu m})$$

$$= 600{,}000 \text{ gm BOD per day}$$

The organic loading per square meter of pond area would be:

$$\text{Organic Loading gm BOD/day/sq m} = \frac{\text{Loading, gm BOD/day}}{\text{Area, sq m}}$$

$$= \frac{600{,}000 \text{ gm BOD/day}}{65{,}000 \text{ sq m}}$$

$$= 9.2 \text{ gm BOD/day/sq m}$$

Therefore, the organic loading would exceed the desired maximum of 5 gms BOD/day/sq m.

9.12 ELIMINATING ALGAE FROM POND EFFLUENTS

Algae are usually present in the effluent from ponds with continuous discharges. Algae can create undesirable impacts on the receiving waters in terms of a loss of esthetic values, increased turbidity, suspended solids and biochemical oxygen demand, and also the development of nuisance conditions. In most areas, the algae in the effluent increase the suspended solids concentration to the point that the NPDES effluent limitation on total suspended solids is exceeded, thus resulting in a permit violation.

Researchers have attempted to develop cost-effective treatment processes for removing algae from pond effluents. These efforts have included the use of centrifuges, chemical coagulation, filtration, microstraining, magnetic separation, and ultrafiltration. Although some of these processes have been very effective, none of these techniques have achieved a high level of acceptance due to the increased treatment costs associated with the process.

A water hyacinth culture is a biological process which appears to be effective in removing algae from effluents and fairly easy to operate and maintain if the proper environmental conditions can be developed.

The water hyacinth is a large floating aquatic plant that can quickly cover the water surface of shallow ponds under proper conditions. Hyacinths are resistant to insects and disease, but are sensitive to high salinity and low temperature.

Studies in Texas reveal that water hyacinth cultures can effectively reduce the five-day biochemical oxygen demand (BOD_5) and suspended solids (SS) in the effluent from facultative ponds. Algae are removed from pond effluents by water hyacinth cultures because the hyacinths remove nutrients from the effluents, and also, because the hyacinths cover the water surface and prevent the algae from receiving any energy from sunlight. Thus, without nutrients and energy, the algae will become inactive and settle to the bottom of the hyacinth culture unit.

In a 30-foot by 210-foot (9 m by 63 m) pilot system operated at an approximate depth of three feet (1 m) with a detention time of five days and a flow rate of 20 gallons per minute (1.2 *L*/s), removals of biochemical oxygen demand (BOD_5) and total suspended solids (TSS) were as follows:

	First Phase		**Second Phase**	
	In	Out	In	Out
BOD_5, mg/*L*	22.5	5.2	46.5	5.7
TSS, mg/*L*	43.0	7.0	117.0	7.5

The first phase ran from June into February and the second from May through August.

Water hyacinth culture is feasible in regions where the climate is suitable. The plants are killed in a matter of hours when surface water temperatures approach freezing, but active growth will begin again when surface water temperatures approach 50°F (10°C).

Seasonal operation of water hyacinth culture ponds is possible in regions where conditions do not permit continuous operation. During the off season, the wastewater would have to be stored. Many ponds are allowed to discharge periodically so facilities may already be available for storage. As a guide, weather conditions suitable for the growing of water hyacinths are similar to those for planting and growing corn.

At least two specially-engineered water hyacinth culture ponds similar to the one shown in Figure 9.12 should be provided. Structures capable of preventing the escape of the water hyacinths must be provided. If hyacinths escape and cause problems in receiving waters, they should be contained and controlled. Each culture pond should be drained and cleaned once a year.

Provisions must be made to maintain a seed stock of water hyacinths during the winter in the colder climates where storage of wastewater is necessary. Reseed when water temperatures increase to 50°F (10°C) in the spring. In ponds where there is a continuous flow of influent, normal temperatures of raw wastewaters are usually warm enough. Also, greenhouses, solar panels, or cooling waters may provide sufficient heat to maintain the water hyacinth culture during the cool winter season. Digester gas, if available, can be burned to heat water to maintain the culture. Another problem with water hyacinths is the fact that odor problems have occurred at night when photosynthesis stops.

Annually, water hyacinth culture ponds should be drained and the plants and accumulated debris should be removed. In areas where year-round production is feasible, at least two culture units should be provided. Each one should be of adequate size to treat the entire plant flow. Alternate operation of culture ponds permits one to be drained and allowed to dry.

Dried plants and debris can be removed using either a front-end loader or hay-baling equipment. Harvested dried plants may be spread on farmland and plowed under for soil improvement. Harvested plants also may be composted for use in parks or disposed of in sanitary landfills. After the culture pond has been cleaned, fill with water and add a few water hyacinths from another culture pond.

For additional information on the operation and maintenance of water hyacinth cultures, contact:

Mr. Ray Dinges
3404 Buck Race
Austin, Texas 78748

9.13 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read Section A.9, Steps in Solving Problems, and A.136, Ponds.

9.14 ACKNOWLEDGMENT

Liberal use has been made of the many papers presented by Professor W. J. Oswald of the University of California at Berkeley on the subject of the treatment of wastes by ponding.

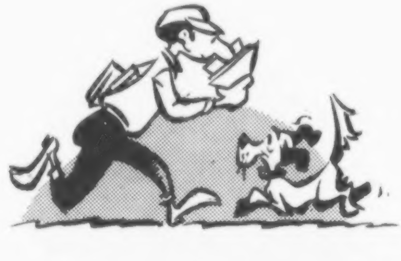
9.15 ADDITIONAL READING

1. *MOP 11* Chapter 13,* "Stabilization Lagoons."
2. *NEW YORK MANUAL*, page 5-43,* "Stabilization Ponds."
3. *TEXAS MANUAL*, Chapter 16, "Stabilization Ponds."
4. *STABILIZATION POND OPERATION AND MAINTENANCE MANUAL*, prepared by Minnesota Pollution Control Agency. Available from National Environmental Training Association, 8687 Via de Ventura, Suite 214, Scottsdale, AZ 85258. Price to members, $17.50, nonmembers, $22.50.
5. *HOW TO IDENTIFY AND CONTROL WATER WEEDS AND ALGAE*, available from the Brown Deer Company, PO Box 23403, Brown Deer, Wisconsin 53223. Price $4.95.
6. *STABILIZATION PONDS OPERATIONS MANUAL*, (EPA 430/9-77-August 1977). Obtain from Environmental Quality, Instructional Resource Center, Room 310, 1200 Chambers Road, Columbus, Ohio 43212. Order No. 015U, price $3.88.
7. "Advanced Wastewater Treatment Natures Way" (Water Hyacinth) *ENVIRONMENTAL SCIENCE AND TECHNOLOGY*, Vol. 12, No. 9, September 1978, p. 1013.

*Depends on edition.

9.16 METRIC CALCULATIONS

Refer to Section 9.119, "Pond Loading," for metric calculations.



END OF LESSON 3 of 3 LESSONS
on
WASTE TREATMENT PONDS

Please answer the discussion and review questions before working the Objective Test.

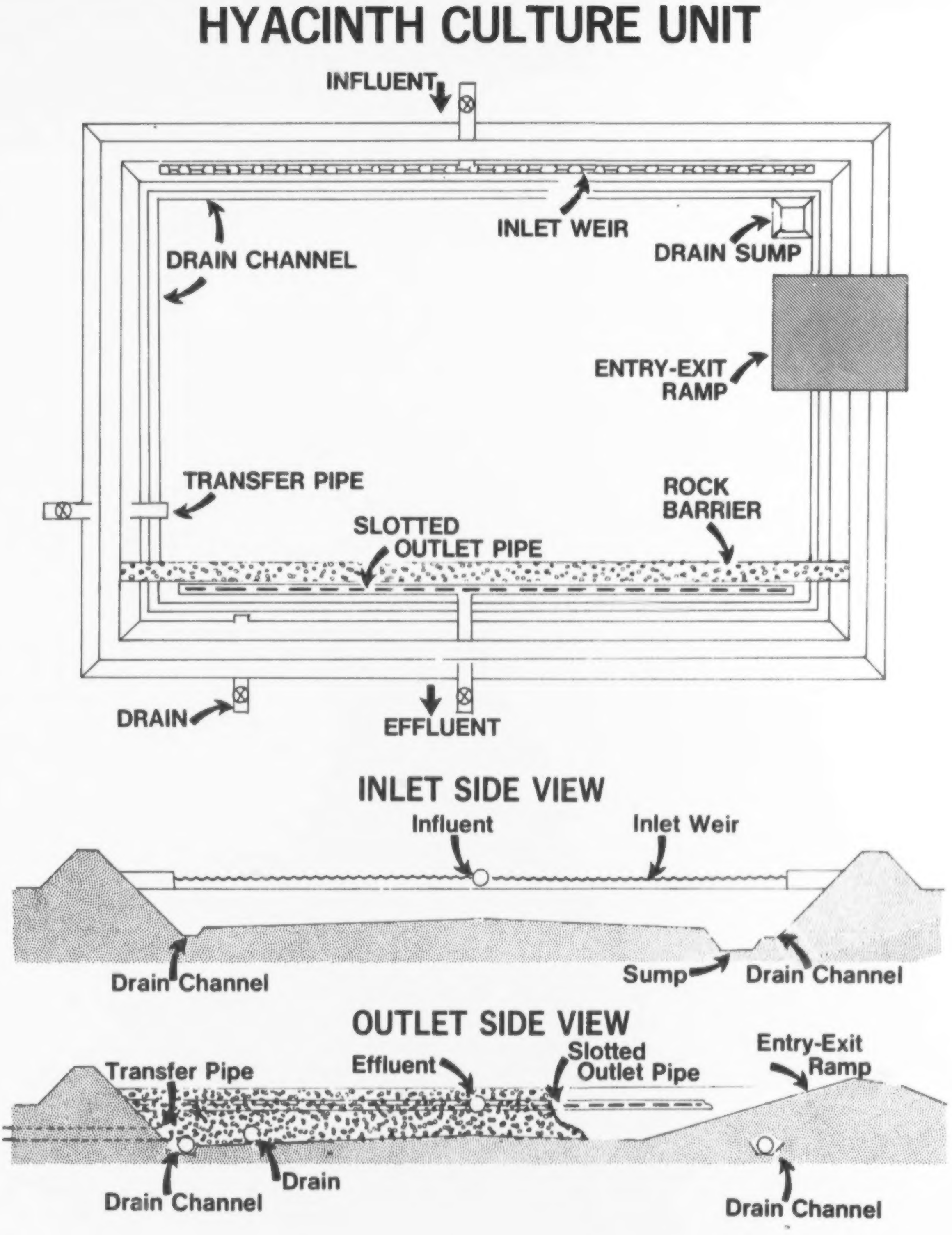

HYACINTH CULTURE UNIT
INFLUENT
INLET WEIR
DRAIN CHANNEL
DRAIN SUMP
ENTRY-EXIT RAMP
TRANSFER PIPE
ROCK BARRIER
SLOTTED OUTLET PIPE
DRAIN
EFFLUENT
INLET SIDE VIEW
Influent
Inlet Weir
Drain Channel
Sump
Drain Channel
OUTLET SIDE VIEW
Transfer Pipe
Effluent
Slotted Outlet Pipe
Entry-Exit Ramp
Drain Channel
Drain
Drain Channel

Fig. 9.12 Water hyacinth culture unit

DISCUSSION AND REVIEW QUESTIONS

Chapter 9. WASTE TREATMENT PONDS

(Lesson 3 of 3 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 2.

13. Why is it desirable for a pond to be isolated from neighbors?
14. How can scum be prevented from leaving a pond?
15. How can erosion of levee slopes be controlled?

A pond receives an inflow of 0.01 MGD from 100 people. The pond is 150 feet long, 150 feet wide, and 4 feet deep. Influent BOD is 200 mg/*L*. Determine the following loading criteria:

16. Detention time in days;
17. Population loading in persons per acre;
18. Hydraulic loading in inches per day; and
19. Organic loading in pounds of BOD applied per day per acre.

PLEASE WORK THE OBJECTIVE TEST NEXT.

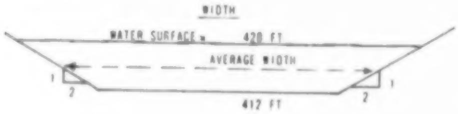
9.17 POND ATTACHMENT (Details of Example Calculations)

References: New York Manual, pages 215-219 (depends on edition) and this Appendix, "How to Solve Wastewater Treatment Plant Problems."

Solution: Example 1

I. Pond Area, sq ft = (Average Width, ft) (Average Length, ft)

A. Calculate average width.



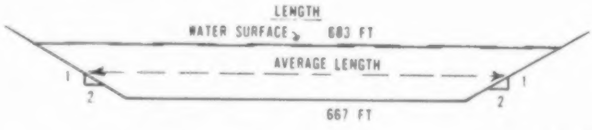
$$\text{Average Width, ft} = \frac{\text{Water Surface Width, ft} + \text{Bottom Width, ft}}{2}$$

$$= \frac{428 \text{ ft} + 412 \text{ ft}}{2} \qquad \begin{array}{r} 428 \\ 412 \\ \hline 840 \end{array}$$

$$= \frac{840 \text{ ft}}{2}$$

$$= 420 \text{ ft} \qquad \begin{array}{r} 420 \\ 2\overline{)840} \\ 8 \\ \hline 04 \\ 4 \\ \hline 00 \end{array}$$

B. Calculate average length.



$$\text{Average Length, ft} = \frac{\text{Water Surface Length, ft} + \text{Bottom Length, ft}}{2}$$

$$= \frac{683 \text{ ft} + 667 \text{ ft}}{2} \qquad \begin{array}{r} 683 \\ 667 \\ \hline 1350 \end{array}$$

$$= \frac{1350 \text{ ft}}{2}$$

$$= 675 \text{ ft} \qquad \begin{array}{r} 675 \\ 2\overline{)1350} \\ 12 \\ \hline 15 \\ 14 \\ \hline 10 \\ 10 \\ \hline 0 \end{array}$$

C. Calculate pond area.

$$\text{Area, sq ft} = (\text{Average Width, ft})(\text{Average Length, ft})$$

$$= (420 \text{ ft})(675 \text{ ft})$$

$$= 283{,}500 \text{ sq ft} \qquad \begin{array}{r} 675 \\ 420 \\ \hline 000 \\ 1350 \\ 2700 \\ \hline 283{,}500 \end{array}$$

Units: When we multiply ft by ft, we obtain square feet or ft^2.

$$\text{Area, acres} = \frac{\text{Area, sq ft}}{43{,}560 \text{ sq ft/ac}}$$

$$= \frac{283{,}500 \text{ sq ft}}{43{,}560 \text{ sq ft/ac}}$$

$$= 6.5 \text{ ac} \qquad \begin{array}{r} 6.508 \\ 43560\overline{)283500.} \\ 261360 \\ \hline 22140\ 0 \\ 21780\ 0 \\ \hline 360\ 00 \\ 000\ 00 \\ \hline 360\ 000 \\ 348\ 480 \\ \hline 11\ 520 \end{array}$$

Units: The sq ft on top (numerator) and bottom (denominator) cancel out, and the /acre on the bottom shifts to the top (numerator).

Our result is 6.508 acres, but we will round off our answer to the nearest tenth (0.1), or 6.5. This is sufficient accuracy.

II. Calculate pond volume.

$$\text{Pond Volume, ac-ft} = (\text{Area, ac})(\text{Depth, ft})$$

$$= (6.51 \text{ ac})(4 \text{ ft}) \qquad \begin{array}{r} 6.51 \\ \times 4 \\ \hline 26.04 \end{array}$$

$$= 26.04 \text{ ac-ft}$$

SUGGESTED ANSWERS

Chapter 9. WASTE TREATMENT PONDS

Answers to questions on page 282.

9.2A Probably. When the greatest organic load per unit of area (high treatment efficiency) is destroyed, objectionable odors may develop.

9.2B Advantages of ponds include low initial and operating costs, and adaptability to fluctuating loads, provided land is cheap.

Answers to questions on page 284.

9.3A The difference between raw wastewater (sewage) lagoons, oxidation ponds, and polishing ponds is the amount of treatment wastewater receives before reaching the pond. Wastewater receiving no treatment flows directly into a raw wastewater (sewage) lagoon. A pond located after a primary clarifier or sedimentation tank is called an "oxidation pond," and a "polishing pond" is placed after a trickling filter or activated sludge plant.

9.3B *AEROBIC* ponds have DO distributed throughout the pond; *ANAEROBIC* ponds do not contain any DO. Most ponds are facultative and have aerobic (have DO) conditions on the surface and are anaerobic (no DO) on the bottom.

9.3C The use of a pond will depend on the detention period. Ponds with detention times less than three days will act like sedimentation tanks. In ponds with a detention period from three to twenty days, the organic material in the influent will be converted to algae, and high concentrations of algae will be found in the effluent. Ponds with longer detention periods provide time for sedimentation of algae and a better effluent.

Answers to questions on page 286.

9.4A Algae produce oxygen from the water (H_20) molecule through photosynthesis.

9.4B Algae simply appear in a pond on their own without seeding. They are found in soil, water, and air and multiply under favorable conditions.

9.4C Organic matter in a pond is converted to carbon dioxide and ammonia and, finally, in the presence of sunlight, to algae. The organic matter in anaerobic bottom sections is first converted by a group of organisms called "acid producers" to carbon dioxide, nitrogen, and organic acids. Next, a group called the "methane fermenters" breaks down the acids and other products of the first group to form methane gas. Another end product of organic reduction is water.

Answers to questions on page 286.

9.5A Bioflocculation is a condition whereby organic materials tend to be transferred from the dispersed form in wastewater to settleable material by mechanical entrapment and assimilation.

9.5B Biological factors influencing the treatment efficiency of a pond include the type of bacteria, type and quantity of algae, activity of organisms, nutrient deficiencies, and toxic substances.

9.5C A pond is not functioning properly when it creates a visual or odor nuisance, or leaves a high BOD, solids, grease, or coliform-group bacteria concentration in the effluent unless it was designed to be anaerobic in the first stages and aerobic in later ponds for final treatment.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 288.

9.6A At least one foot of water should cover the pond bottom before wastes are introduced to prevent decomposing solids from being exposed and causing odor problems.

9.6B Ponds should be started during the warmer months because higher temperatures are associated with efficient treatment processes.

9.6C A definite green color in a pond indicates a flourishing algae population and is a good sign.

9.6D When bubbles are observed coming to the pond surface near the inlet, this indicates that the solids which settled to the bottom are being decomposed anaerobically by bacterial action.

Answers to questions on page 290.

9.7A Scum should not be allowed to accumulate on the surface of a pond because it is unsightly, may prevent sunlight from reaching the algae, and an odor-producing species of algae may develop on the scum. Also scum can become a source of botulism.

9.7B Scum accumulations may be broken up with rakes, jets of water, or by use of outboard motors.

9.7C Most odors are caused in ponds by overloading or poor housekeeping.

9.7D To prepare for an odor problem, a careful plan for emergency odor control must be developed. For example, an odor control chemical should be available before an odor problem develops. Sodium nitrate or a floating aerator will help control odors and improve treatment of the wastewater.

9.7E Weeds are objectionable in and around ponds because they provide a shelter for the breeding of mosquitoes and scum accumulation and also hinder pond circulation.

9.7F Weeds may be controlled by herbicides and soil sterilants.

9.7G Insects should be controlled because they may, in sufficient numbers, be a serious nuisance to nearby residential areas, farm workers, recreation sites, industrial plants, and drivers on highways.

9.7H A pond should be lowered before the application of an insecticide to improve the mortality of insects and reduce the effect of the insecticide on the receiving waters by holding the wastewater at least one day. Lowering of the pond also will dry up weeds and insects.

Answers to questions on page 292.

9.7I The contents of ponds are recirculated to allow algae and other aerobic organisms to become thoroughly mixed with incoming raw wastewater.

9.7J Ponds that are operated on a batch basis may discharge only once (fall) or twice (fall and spring) a year.

9.7K To develop an operating strategy for ponds, consider the following factors:

1. Maintain constant water elevations in the ponds;
2. Distribute inflow equally to ponds;
3. Keep pond levees or dikes in good condition; and
4. Observe and test pond condition.

Answers to questions on page 298.

9.8A Surface aerators have been used to provide additional air for ponds and air for ponds operated as aerated lagoons.

9.9A When a pond turns dull green, grey, or colorless, generally the pH and dissolved oxygen have dropped too low. This condition may be caused by overloading or lack of circulation.

9.9B pH, temperature, and dissolved oxygen should be measured to provide a record of pond performance and to indicate the status (health) of the pond and whether corrective action is or may be necessary. DO may be expected to be low in the morning and increase with sunlight hours.

9.9C When the pH and dissolved oxygen drop dangerously low, the loading should be reduced or stopped. Recirculating water from a healthy pond to the problem pond should help the situation. Recirculation from outlet to inlet areas is beneficial for seeding, DO, and mixing.

9.9D

$$\begin{aligned}\text{BOD Removal, \%} &= \frac{(\text{In - Out})}{\text{In}} \times 100\% \\ &= \frac{(200\text{ mg}/L - 40\text{ mg}/L)}{200\text{ mg}/L} \times 100\% \\ &= \frac{160\text{ mg}/L}{200\text{ mg}/L} \times 100\% \\ &= 0.80 \times 100\% \\ &= 80\%\end{aligned}$$

Answers to questions on page 298.

9.10A Walkways over ponds should have handrails and non-skid walking surfaces.

9.10B An operator should be accompanied by a helper when performing any dangerous task because immediate aid might prevent serious injury or loss of life.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 305.

9.11A Some wastes are not easily treated by ponds because they contain substances with interfering concentrations which hinder algal or bacterial growth.

9.11B The minimum recommended pond operating depth is three feet. At shallower depths, aquatic weeds become a nuisance and pond performance is apt to be irregular.

9.11C The inlet to a pond should be submerged to distribute the heat of the influent as much as possible and to minimize the occurrence of floating material.

9.11D The outlet of a pond should be submerged to prevent the discharge of floating material.

9.11E The discharge of floating material over a surface outlet may be corrected by constructing a baffle around the outlet.

9.11F Free overfalls should be avoided to minimize odors, foaming, and gas entrapment which may hamper the flow of water in pipes. They are generally controlled with pipes at the outfall.

9.11G Any shallow pond is apt to be irregular in performance because the algae grow, die, and settle to the bottom, thus creating a new organic load. Algae *PRODUCE* and *STORE* organic matter that must be stabilized later. Objectionable "burps" of unstable material are common in pond effluents.

9.11H The influent to a pond should be metered to justify budgets, indicate unexpected fluctuations in flows which may cause upsets, and provide data for future expansion when necessary.

Answers to questions on page 307.

9.11I Given:
Flow = 2.0 MGD
Population = 20,000 people
Influent BOD = 180 mg/*L*
Pond Area = 24 acres
Average Depth = 4 feet

Reqd.:
Detention Time
Organic Loading
Population Loading
Hydraulic Loading

Determine pond volume in acre-feet.

$$\begin{aligned}\text{Volume, ac-ft} &= (\text{Area, ac})\ (\text{Depth, ft}) \\ &= (24\text{ ac})\ (4\text{ ft}) \\ &= 96\text{ ac-ft}\end{aligned}$$

Convert flow rate from MGD to ac-ft per day.

$$\begin{aligned}\text{Flow, ac-ft/day} &= \frac{2{,}000{,}000\text{ gal}}{\text{day}} \times \frac{\text{cu ft}}{7.48\text{ gal}} \times \frac{\text{acre}}{43{,}560\text{ sq ft}} \\ &= 6.1\text{ ac-ft/day}\end{aligned}$$

Determine detention time in days.

$$\begin{aligned}\text{Detention Time, days} &= \frac{\text{Pond Volume, ac-ft}}{\text{Flow Rate, ac-ft/day}} \\ &= \frac{96\text{ ac-ft}}{6.1\text{ ac-ft/day}} \\ &= 15.7\text{ days}\end{aligned}$$

$$\begin{array}{r} 15.7 \\ 6.1\overline{)96.0} \\ \underline{61} \\ 350 \\ \underline{305} \\ 450 \\ 427 \end{array}$$

Calculate organic loading in pounds of BOD per day per acre.

$$\begin{aligned}\text{Organic Load, lb BOD/day/ac} &= \frac{(\text{BOD, mg}/L)\ (\text{Flow, MGD})\ (8.34\text{ lbs/gal})}{\text{Area, ac}} \\ &= \frac{180\text{ lb}}{\text{M lb}} \times \frac{2.0\text{ MG}}{\text{day}} \times \frac{8.34\text{ lbs}}{\text{gal}} \times \frac{1}{24\text{ ac}} \\ &= 125\text{ lb BOD/day/ac}\end{aligned}$$

Estimate the population loading in persons per acre.

$$\text{Population Loading, persons/ac} = \frac{\text{Population, persons}}{\text{Area, ac}}$$

$$= \frac{20{,}000 \text{ persons}}{24 \text{ ac}}$$

$$= 833 \text{ persons/ac}$$

Calculate the hydraulic loading in inches per day.

$$\text{Hydraulic Loading, in/day} = \frac{\text{Pond Depth, in}}{\text{Detention Time, days}}$$

$$= \frac{(4 \text{ ft})(12 \text{ in/ft})}{15.7 \text{ days}}$$

$$= \frac{48}{15.7}$$

$$= 3.06 \text{ in/day}$$

$$\begin{array}{r} 3.057 \\ 15.7\overline{)48.0} \\ \underline{47.1} \\ 900 \\ \underline{785} \\ 1150 \\ 1099 \end{array}$$

END OF ANSWERS TO QUESTIONS IN LESSON 3

OBJECTIVE TEST

Chapter 9. WASTE TREATMENT PONDS

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

1. Scum is not allowed to enter a waste treatment pond.
   1. True
   2. False
2. Photosynthesis is a process requiring sunlight.
   1. True
   2. False
3. Algae poisons a facultative pond.
   1. True
   2. False
4. A waste treatment pond is a biological process.
   1. True
   2. False
5. A pH of 7.0 represents an acid condition.
   1. True
   2. False
6. Toxicity has to do with insect growth.
   1. True
   2. False
7. A scum raft is a piece of equipment used when collecting samples from a pond.
   1. True
   2. False
8. A "polishing pond" is a form of tertiary treatment.
   1. True
   2. False
9. The depth of a waste treatment pond should be less than three feet.
   1. True
   2. False
10. Dissolved oxygen in a pond can be increased by wind action.
    1. True
    2. False
11. A pond population loading is expressed in terms of the number of persons per acre of pond surface.
    1. True
    2. False
12. Operation of a waste treatment pond does *NOT* require expensive equipment.
    1. True
    2. False
13. A waste treatment pond is economical to construct.
    1. True
    2. False
14. Water hyacinth cultures have been used to produce effluents free of algae.
    1. True
    2. False
15. When ponds are operated in series, the influent is split and a portion is diverted to each of two ponds.
    1. True
    2. False
16. Usually ponds do not become overloaded during storms and periods of high runoff.
    1. True
    2. False
17. The effluent should leave the final pond
    1. At the surface.
    2. Just below the surface with a scum baffle around the outlet.
    3. At the bottom of the pond.

18. The pond outfall should be
    1. Free.
    2. Submerged.
    3. Wherever it is convenient.

19. Minimum depth for weed control in a facultative pond should be
    1. 3 feet.
    2. 4 feet.
    3. 5 feet.

20. Ponds are used to
    1. Grow mosquitoes.
    2. Grow tules.
    3. Ice skate on.
    4. Provide a surface for evaporation.
    5. Store wastewater while it is treated.

21. Facultative ponds are
    1. Aerobic on the top and anaerobic on the bottom.
    2. Completely aerobic.
    3. Faulty operating ponds.
    4. The most common type in current use.
    5. Very shallow ponds.

22. Advantages of ponds for smaller installations include
    1. Capability to handle fluctuating hydraulic loads.
    2. Low cost to build and operate.
    3. No insect problems.
    4. No maintenance.
    5. Satisfactory treatment of wastes.

23. Ponds are ______ simple to operate. (Select best answer.)
    1. Deceptively
    2. Not
    3. Quite
    4. Sort of
    5. Very

24. When starting a pond, wastewater should be added when the
    1. Bottom is covered with grass.
    2. Mayor returns from his vacation.
    3. Pond bottom is covered with at least one foot of water.
    4. Pond is empty.
    5. Wind is blowing in the right direction.

25. Important operation and maintenance aspects of ponds include control of
    1. Drying beds.
    2. Odors.
    3. Scum.
    4. Waste gas burner.
    5. Weeds and insects.

26. Scum rafts may be broken up by
    1. A thrashing machine.
    2. Agitation with garden rakes.
    3. Breaking down the bindings.
    4. Jets of water from pumps.
    5. The use of outboard motors on boats.

27. Ponds may not operate properly if
    1. Temperature stays below freezing for a long time.
    2. The influent contains a powerful fungicide.
    3. The influent has a high sulfur content.
    4. The influent organic matter content fluctuates tremendously every few days.
    5. There is no scum blanket.

28. Observations which indicate that a pond is operating or being maintained properly include
    1. A definite green color of the pond.
    2. Duckweed floating on the pond surface.
    3. Lots of mosquitoes swarming around the pond area.
    4. Scum on the pond surface.
    5. Tules growing along the edge of the pond.

29. To protect levee banks from erosion, the operator may
    1. Add more soil to replace the material washed away.
    2. Dump small pieces of broken street materials, curbs and gutters along the water line.
    3. Place bricks and other materials from building demolition along the water line.
    4. Plant tules along the water line.
    5. Release some beavers to repair the levee bank.

30. When ponds discharge only once or twice a year, discharges may be made
    1. During the recreation season.
    2. When all the ponds are full.
    3. When downstream water users need water.
    4. When flows are high in the receiving waters.
    5. With the approval of the state regulatory agency.

31. Pond performance can be indicated by what tests?
    1. Carbon dioxide.
    2. Dissolved oxygen.
    3. Hardness.
    4. Methane.
    5. pH.

32. Pond performance depends on
    1. Lack of short-circuiting.
    2. pH.
    3. Sunlight.
    4. Surface area.
    5. Type and quantity of algae.

33. Pond loadings may be expressed in
    1. Acres of people per day.
    2. Acres per day of BOD.
    3. Gallons of BOD per day per acre.
    4. Pounds BOD/day/acre.
    5. Persons per acre.

34. Dissolved oxygen in a pond is increased by
    1. Algae liberating oxygen from the water molecule.
    2. Photosynthesis.
    3. Sludge gases from bottom deposits floating to the surface.
    4. Surface aerators.
    5. Wind action.

35. Tests on samples *FROM POND CONTENTS* which reveal if the pond is functioning properly include
    1. BOD.
    2. Chlorine residual.
    3. Coliforms.
    4. DO.
    5. pH.

36. Potentially hazardous duties an operator may have to conduct while working around ponds include
    1. Collecting samples from a boat.
    2. Cutting weeds near electrical wires.
    3. Entering an enclosed headworks structure.
    4. Removing scum from the pond surface.
    5. Spraying pesticides.

37. Estimate the population served if the inflow to a plant is 1.2 MGD. Assume a flow of 100 gallons per person per day.
    1. 1200.
    2. 6000.
    3. 12,000.
    4. 120,000.
    5. None of these.

38. Two ponds serve a summer resort and are operated in series. They cover an area of 150 ft by 250 ft (average width and length of both ponds combined). The average depth is four feet, and the average inflow is 25,000 gpd. The detention time is approximately
    1. 20 days.
    2. 45 days.
    3. 50 days.
    4. 55 days.
    5. 80 days

39. And when the influent BOD is 200 mg/*L* for the ponds in problem 38, the organic loading is approximately
    1. 40 lb BOD/day/ac.
    2. 42 lb BOD/day/ac.
    3. 45 lb BOD/day/ac.
    4. 48 lb BOD/day/ac.
    5. 70 lb BOD/day/ac.

Review Question:

40. Estimate the velocity in a grit channel if a stick travels 30 feet in 40 seconds.
    1. 0.50 ft/sec.
    2. 0.75 ft/sec.
    3. 1.00 ft/sec.
    4. 1.25 ft/sec.
    5. 1.33 ft/sec.

END OF OBJECTIVE TEST

CLEANWATER, U.S.A.
WATER POLLUTION CONTROL PLANT

MONTHLY RECORD ________ 19__ OPERATOR: ____________

DATE	DAY	WEATHER	TIME OF VISIT	FLOW (MGD) EFFLUENT	TEMP. °F NO. 1 POND	TEMP. °F NO. 2 POND	pH NO. 1 POND	pH NO. 2 POND	D.O. NO. 1 POND	D.O. NO. 2 POND	B.O.D. INFLUENT	B.O.D. EFFLUENT	CL$_2$ FEED RATE LB./DAY	CL$_2$ RESIDUAL Mg./L.	E-COLI. M.P.N./100	MIXING HRS. NO. 1 POND	MIXING HRS. NO. 2 POND	REMARKS
1	T												35					
2	W	OVER CAST	9:30 A.M.	0.025	68	70	7.6	7.9	0.8	1.4	183	32	35	3.2	62	-0-	-0-	EFFL. SS = 45 mg/l
3	T	CLEAR	2:00 P.M.	0.038	76	79	7.7	8.4	1.3	8.7			35	1.4				
4	F												"					
5	S												"					
6	S												"					
7	M	CLEAR	10:00 A.M.	0.026	70	74	7.6	8.1	1.2	7.6			"					
8	T												"					
9	W	CLEAR	10:30 A.M.	0.027	69	73	7.6	8.1	1.1	7.8	158	29	35	0.8	2400	-0-	-0-	EFFL. SS = 53 mg/l
10	T												"					
11	F	CLEAR HOT	3:15 P.M.	0.039	77	80	7.6	8.3	1.5	11.2			"					
12	S												"					
13	S												"					
14	M	CLEAR	9:30 A.M.	0.023	70	75	7.8	8.5	1.9	7.6			"					
15	T												40					INCREASED Cl$_2$ FEED RATE TO 40#/DAY
16	W	CLEAR	1:30 P.M.	0.031	75	79	7.8	8.4	1.7	10.6	162	33	40	4.2	700	-0-	-0-	EFFL. SS = 37 mg/l
17	T												40					
18	F	CLEAR	3:30 P.M.	0.037	79	85	7.8	8.6	2.1	14.5			40	2.5	23			
19	S												"					
20	S												40	2.8				
21	M												"					DECLARED HOLIDAY - NO PLANT CHECK
22	T	CLEAR	9:00 A.M.	0.020	71	76	7.6	8.4	1.0	7.8			40	5.6				
23	W	CLEAR	10:30 A.M.	0.028	72	78	7.7	8.4	1.0	8.1	178	30	40	5.0	6	-0-	-0-	EFFL SS = 48 mg/l
24	T												"					
25	F	CLEAR	2:15 P.M.	0.035	80	87	7.8	8.5	1.3	11.4			40	3.8				
26	S												"					
27	S												"					
28	M	CLEAR	10:00 A.M.	0.026	73	79	7.7	8.5	1.1	8.6			40	4.7				Cl$_2$ FEED RATE BACK TO 35#/DAY
29	T												35					
30	W	CLEAR	4:15 P.M.	0.038	81	88	7.8	8.5	1.8	15.3	168	35	35	1.1	6	-0-	-0-	EFFL. SS = 57 mg/l
31																		
MAX.				0.039	81	88	7.8	8.6	2.1	15.3	183	35	40	5.6	2400	-0-	-0-	
MIN.				0.020	68	70	7.6	7.9	0.8	7.6	162	29	35	0.8	6	-0-	-0-	
AVG.		CLEAR		0.030	73	78	7.7	8.3	1.3	9.2	169	31	37.2	2.7	62	-0-	-0-	

SUMMARY DATA

% REMOVAL B.O.D.	81.6 %
LBS. B.O.D. / ACRE / DAY	52.8
DETENTION TIME — DAYS	86.7

PONDS OPERATED IN SERIES ALL MONTH.

MIXERS NOT OPERATED DURING MONTH.

COST DATA

MAN DAYS [illegible] PAYROLL	122.76
POWER PURCHASED	34.80
OTHER UTILITIES (GAS, H$_2$O)	NONE
GASOLINE, OIL, GREASE	NONE
CHEMICALS & SUPPLIES	69.30
MAINTENANCE	NONE
VEHICLE COSTS	48.70
OTHER	NONE
TOTAL	$ 275.56
OPERATING COST / CAPITA / MO.	$ 0.12
COST / 1000 GAL. TREATED	$ 0.296

FLOW METER:
LAST 232602
1st 231672
TOTAL 0.930 MG

ELECTRIC METER:
LAST 5978
1st 5817
MULT. 40 x 161 = 6440 KWH

CHAPTER 10

DISINFECTION AND CHLORINATION

by

Leonard W. Hom

(With a special section by J.L. Beals)

Revised

by

Tom Ikesaki

TABLE OF CONTENTS

Chapter 10. Disinfection and Chlorination

Revised by Tom Ikesaki

Page

OBJECTIVES 324

GLOSSARY 325

LESSON 1

10.0 Need for Disinfection 329
- 10.00 Effectiveness in Microorganism Removal by Various Treatment Processes 329
- 10.01 Disinfection 329
- 10.02 Reaction of Chlorine in Wastewater 331
  - 10.020 Free Chlorine (Cl_2) 331
  - 10.021 Hypochlorite (OCl^-) 331
  - 10.022 Chlorine Dioxide (ClO_2) 332
- 10.03 Reactions of Chlorine Solutions with Impurities in Wastewater 332
  - 10.030 Inorganic Reducing Materials 332
  - 10.031 Reaction with Ammonia 332
- 10.04 Hypochlorination of Wastewater 333
- 10.05 Factors Influencing Disinfection 333
- 10.06 Chlorine Requirements 333

LESSON 2

10.1 Points of Chlorine Application 336
- 10.10 Collection System Chlorination 336
- 10.11 Prechlorination 336
- 10.12 Plant Chlorination 336
- 10.13 Chlorination Before Filtration 336
- 10.14 Postchlorination 336

10.2 Chlorination Process Control 338
- 10.20 Chlorinator Control 338
  - 10.200 Manual Control 338
  - 10.201 Start-Stop Control 338
  - 10.202 Step-Rate Control 338

10.203 Timed-Program Control 338

10.204 Flow-Proportional Control 338

10.205 Chlorine Residual Control 338

10.206 Compound Loop Control 338

10.21 Chlorination Control Nomogram 339

10.22 Hypochlorinator Feed Rate and Control 341

10.23 Chlorine Solution Discharge Lines, Diffusers, and Mixing 342

10.230 Solution Discharge Lines 342

10.231 Chlorine Solution Diffusers 342

10.232 Mixing 342

10.24 Measurement of Chlorine Residual 342

10.25 Start-Up of Chlorinators 342

10.250 Gas Chlorinators 344

10.251 Liquid Chlorine Chlorinators 344

10.26 Normal and Abnormal Operation 345

10.260 Container Storage Area 345

10.261 Evaporators 345

10.262 Chlorinators, Including Injectors 347

10.27 Shutdown of a Chlorinator 349

10.270 Short-Term Shutdown 349

10.271 Long-Term Shutdown 349

10.28 Operational Strategy 349

10.29 Chlorine Troubleshooting Guide 350

LESSON 3

10.3 Chlorine Safety Program 354

10.30 Chlorine Hazards 354

10.31 Why Chlorine Must be Handled with Care 354

10.32 Protect Yourself from Chlorine 355

10.33 First Aid Measures 355

10.4 Chlorine Handling 356

10.40 Chlorine Containers 356

10.400 Cylinders 356

10.401 Ton Tanks 356

10.402 Chlorine Tank Cars 356

10.41 Removing Chlorine from Containers 362

10.410 Connections 362

10.411 Valves 362

10.412 Ton Tanks 362

        10.413 Railroad Tank Cars 362
    10.42 Chlorine Leaks 364

LESSON 4

10.5 Chlorination Equipment and Maintenance 366
    10.50 Chlorinators 366
    10.51 Evaporators 366
    10.52 Hypochlorinators 371
    10.53 Chlorine Dioxide Facility 371
    10.54 Installation and Maintenance 371
    10.55 Installation Requirements 373
        10.550 Piping, Valves, and Manifolds 373
        10.551 Chlorinator Injector Water Supply 373
    10.56 Review of Plans and Specifications 374
10.6 Other Uses of Chlorine 374
    10.60 Odor Control 374
    10.61 Protection of Structures 375
    10.62 Aid to Treatment 375
        10.620 Sedimentation and Grease Removal 375
        10.621 Trickling Filters 375
        10.622 Activated Sludge 375
        10.623 Reduction of BOD 375
10.7 Acknowledgments 375

LESSON 5

10.8 Dechlorination 376
    10.80 Need for Dechlorination 376
    10.81 Sulfur Dioxide (SO_2) 376
        10.810 Properties 376
        10.811 Chemical Reaction of Sulfur Dioxide with Wastewater 377
        10.812 Application Point 377
    10.82 Sulfur Dioxide Hazards 377
        10.820 Exposure Responses to Sulfur Dioxide 377
        10.821 Detection of Leaks 378
        10.822 What to Do in Case of Leaks 378
        10.823 Employees Authorized to Work on Leaks 378
        10.824 Safety with Sulfur Dioxide 378
        10.825 First Aid 378
        10.826 Emergency Safety Equipment 379

10.83 Sulfur Dioxide Supply System 379

  10.830 Sulfur Dioxide Containers 379

  10.831 Supply Piping 379

  10.832 Valves 379

10.84 Sulfonation System 380

  10.840 Evaporator 380

  10.841 Sulfonator 380

  10.842 Injector 380

10.85 Sulfonator Controls 380

  10.850 Sulfonator Feed-Rate Control 380

  10.851 Control Facilities 380

  10.852 Selection of Method of Control 381

10.86 Determination of Residual Sulfur Dioxide in Wastewater 381

10.87 Operation of Sulfonator Process 381

  10.870 Start-Up of a New System 381

  10.871 Start-Up of Gas Sulfonators 382

  10.872 Troubleshooting the Gas Sulfonator System 383

  10.873 Start-Up of Liquid Sulfonators 384

  10.874 Troubleshooting the Liquid Sulfonator System 385

  10.875 Normal and Abnormal Operation 386

  10.876 Operational Strategy 386

  10.877 Troubleshooting Sulfonation System 386

  10.878 Sulfonation System Shutdown Procedures 387

10.88 Maintenance of the Sulfur Dioxide Systems 387

  10.880 Supply Area 387

  10.881 Piping 387

  10.882 Evaporators 387

  10.883 Sulfonators 387

10.9 Arithmetic Assignment 387

10.10 Additional Reading 387

10.11 Metric Calculations 388

  10.110 Conversion Factors 388

  10.111 Problem Solutions 388

OBJECTIVES

Chapter 10. DISINFECTION AND CHLORINATION

Following completion of Chapter 10, you should be able to do the following:

1. Explain the principles of wastewater disinfection with chlorine,
2. Control the chlorination process to obtain the desired effluent disinfection,
3. Handle chlorine safely,
4. Detect chlorine leaks and take appropriate corrective action,
5. Inspect new chlorination facilities for proper installation,
6. Schedule and conduct chlorination operation and maintenance duties,
7. Recognize factors that indicate the chlorination process is not performing properly, identify the source of the problem, and take corrective action,
8. Conduct your duties in a safe fashion,
9. Determine chlorine dosages,
10. Explain applications and limitations of uses of chlorine other than for disinfection,
11. Keep records of chlorination operation, and
12. Safely operate and maintain a sulfur dioxide dechlorination system.

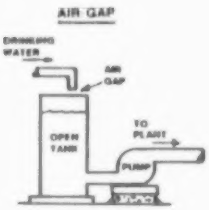
GLOSSARY

Chapter 10. DISINFECTION AND CHLORINATION

ORTHOTOLIDINE • HYPO-
CHLORINATORS • SEPTICITY
ENTERIC ATITIS
COLIF HOGENIC
RESIDUAL ORINE • MPN
SAPROPHYTES • MOTILE

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the potable water.



AIR PADDING AIR PADDING

Pumping dry air into a container to assist with the withdrawal of a liquid or to force a liquid gas such as chlorine or sulfur dioxide out of a container.

AMBIENT TEMPERATURE (AM-bee-ent) AMBIENT TEMPERATURE

Temperature of the surroundings.

AMPEROMETRIC (am-PURR-o-MET-rick) AMPEROMETRIC

A method of measurement that records electric current flowing or generated, rather than recording voltage. Amperometric titration is a means of measuring concentrations of certain substances in water.

BACTERIA (back-TEAR-e-ah) BACTERIA

Bacteria are living organisms, microscopic in size, which consist of a single cell. Most bacteria utilize organic matter for their food and produce waste products as the result of their life processes.

BIODEGRADATION (BUY-o-de-grah-DAY-shun) BIODEGRADATION

The breakdown of organic matter by bacteria to more stable forms which will not create a nuisance or give off foul odors.

BREAKOUT OF CHLORINE BREAKOUT OF CHLORINE

A point at which chlorine leaves solution as a gas because chlorine feed rate is too high. The solution is saturated and cannot dissolve any more chlorine.

BREAKPOINT CHLORINATION BREAKPOINT CHLORINATION

Addition of chlorine to water or wastewater until the chlorine demand has been satisfied and further additions of chlorine result in a residual that is directly proportional to the amount added beyond the breakpoint.

CHLORAMINES (KLOR-a-means) CHLORAMINES

Chloramines are compounds formed by the reaction of chlorine with ammonia.

CHLORINATION (KLOR-i-NAY-shun) CHLORINATION

The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

CHLORINE DEMAND CHLORINE DEMAND

Chlorine demand is the difference between the amount of chlorine added to wastewater and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of the impurities in the water.

Chlorine Demand, mg/*L* = Chlorine Applied, mg/*L* – Chlorine Residual, mg/*L*

CHLORINE REQUIREMENT CHLORINE REQUIREMENT

The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or destroying some chemical in the water. In each case a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CHLORORGANIC (chlor-or-GAN-nick) CHLORORGANIC

Chlororganic compounds are organic compounds combined with chlorine. These compounds generally originate from, or are associated with, living or dead organic materials.

COLIFORM (COAL-i-form) COLIFORM

One type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes other environmental sources.

COLORIMETRIC MEASUREMENT COLORIMETRIC MEASUREMENT

A means of measuring unknown concentrations of water quality indicators in a sample by measuring the sample's color intensity. The color of the sample after the addition of specific chemicals (reagents), is compared with colors of known concentrations.

COMBINED AVAILABLE CHLORINE COMBINED AVAILABLE CHLORINE

The concentration of chlorine which is combined with ammonia (NH_3) as chloramine or as other chloro derivatives, yet is still available to oxidize organic matter.

COMBINED AVAILABLE RESIDUAL CHLORINE COMBINED AVAILABLE RESIDUAL CHLORINE

That portion of the total residual chlorine which remains in water or wastewater at the end of a specified contact period and reacts chemically and biologically as chloramines or organic chloramines.

COMBINED RESIDUAL CHLORINATION COMBINED RESIDUAL CHLORINATION

The application of chlorine to water or wastewater to produce a combined chlorine residual. The residual may consist of chlorine compounds formed by the reaction of chlorine with natural or added ammonia (NH_3) or with certain organic nitrogen compounds.

DECHLORINATION (dee-KLOR-i-NAY-shun) DECHLORINATION

The removal of chlorine from the effluent of a treatment plant.

DEGRADATION (de-gray-DAY-shun) DEGRADATION

The conversion of a substance to simpler compounds.

DEW POINT DEW POINT

The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air.

DISINFECTION (DIS-in-FECK-shun) DISINFECTION

The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being most frequently used in water and wastewater treatment plants. Compare with STERILIZATION.

EDUCTOR (e-DUCK-tor) EDUCTOR

A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump; sometimes used instead of a suction pump.

ELECTRON ELECTRON

An extremely small (microscopic), negatively charged particle. An electron is much too small to be seen with a microscope.

ENTERIC

ENTERIC

Intestinal.

ENZYMES (EN-zimes)

ENZYMES

Enzymes are organic substances which are produced by living organisms and speed up chemical changes.

FILAMENTOUS ORGANISMS (FILL-a-MEN-tuss)

FILAMENTOUS ORGANISMS

Organisms that grow in a thread or filamentous form.

FREE AVAILABLE CHLORINE

FREE AVAILABLE CHLORINE

The amount of chlorine available in water. This chlorine may be in the form of dissolved gas (Cl_2), hypochlorous acid (HOCl), or hypochlorite ion (OCl^-), but does not include chlorine combined with an amine (ammonia or nitrogen) or other organic compound.

FREE AVAILABLE RESIDUAL CHLORINE

FREE AVAILABLE RESIDUAL CHLORINE

That portion of the total residual chlorine remaining in water or wastewater at the end of a specified contact period. Residual chlorine will react chemically and biologically as hypochlorous acid (HOCl) or hypochlorite ion (OCl^-).

FREE CHLORINE

FREE CHLORINE

Free chlorine is chlorine (Cl_2) in a liquid or gaseous form. Free chlorine combines with water to form hypochlorous (HOCl) and hydrochloric (HCl) acids. In wastewater free chlorine usually combines with an amine (ammonia or nitrogen) or other organic compounds to form combined chlorine compounds.

FREE RESIDUAL CHLORINE

FREE RESIDUAL CHLORINE

The result of the application of chlorine or chlorine compounds to water or wastewater to produce a free available chlorine residual directly or through the destruction of ammonia (NH_3) or certain organic nitrogenous compounds.

HEPATITIS

HEPATITIS

Hepatitis is an acute viral infection of the liver. Yellow jaundice is one symptom of hepatitis.

HYPOCHLORINATION (hi-poe-KLOR-i-NAY-shun)

HYPOCHLORINATION

The application of hypochlorite compounds to water or wastewater for the purpose of disinfection.

HYPOCHLORINATORS (hi-poe-KLOR-i-NAY-tors)

HYPOCHLORINATORS

Chlorine pumps or devices used to feed chlorine solutions made from hypochlorites such as bleach (sodium hypochlorite) or calcium hypochlorite.

HYPOCHLORITE (hi-poe-KLOR-ite)

HYPOCHLORITE

Hypochlorite compounds contain chlorine and are used for disinfection. These compounds are similar to strong bleach. They are available as liquids or solids (powder, granules and pellets) in barrels, drums and cans.

MPN (EM-PEA-EN)

MPN

MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume. Expressed as density or population of organisms per 100 ml.

MOTILE (MO-till)

MOTILE

Motile organisms exhibit or are capable of movement.

NITROGENOUS (nye-TROG-en-ous)

NITROGENOUS

Nitrogenous compounds contain nitrogen.

NOMOGRAM

NOMOGRAM

A chart or diagram containing three or more scales used to solve problems with three or more variables instead of using mathematical formulas.

ORTHOTOLIDINE (or-tho-TOL-i-dine)

ORTHOTOLIDINE

Orthotolidine is a colorimetric indicator of chlorine residual. If chlorine is present, a yellow-colored compound is produced. This method is no longer approved for tests of effluent chlorine residual.

OXIDIZING AGENT

OXIDIZING AGENT

An oxidizing agent is any substance, such as oxygen (O_2) and chlorine (Cl_2), that can add (take on) electrons. When oxygen or chlorine is added to wastewater, organic substances are oxidized. These oxidized organic substances are more stable and less likely to give off odors or to contain disease bacteria. The opposite of REDUCING AGENT.

PARASITIC BACTERIA (PAIR-a-SIT-tick) PARASITIC BACTERIA

Parasitic bacteria are those bacteria which normally live off another living organism, known as the "host."

PATHOGENIC ORGANISMS (path-o-JEN-nick) PATHOGENIC ORGANISMS

Bacteria, viruses or cysts which can cause disease (typhoid, cholera, dysentery). There are many types of bacteria which do *NOT* cause disease and which are *NOT* called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.

POSTCHLORINATION POSTCHLORINATION

The addition of chlorine to the plant discharge or effluent, *FOLLOWING* plant treatment, for disinfection purposes.

POTABLE WATER (POE-ta-bl) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered safe for domestic consumption.

PRECHLORINATION PRECHLORINATION

The addition of chlorine at the headworks of the plant *PRIOR TO* other treatment processes mainly for odor and corrosion control. Also applied to aid disinfection, to reduce plant BOD load, to aid in settling, to control foaming in Imhoff units and to help remove oil.

REAGENT (re-A-gent) REAGENT

A substance which takes part in a chemical reaction and is used to measure, detect, or examine other substances.

REDUCING AGENT REDUCING AGENT

A reducing agent is any substance, such as the chloride ion (Cl^-) and the sulfide ion (S^{-2}), that can give up electrons. The opposite of OXIDIZING AGENT.

RELIQUEFACTION (re-LICK-we-FACK-shun) RELIQUEFACTION

The return of a gas to a liquid. For example, a condensation of chlorine gas returning to the liquid form.

RESIDUAL CHLORINE RESIDUAL CHLORINE

Residual chlorine is the amount of chlorine remaining after a given contact time and under specified conditions.

ROTAMETER ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.

SAPROPHYTES (SAP-pro-fights) SAPROPHYTES

Organisms living on dead or decaying organic matter. They help natural decomposition of the organic solids in wastewater.

SEPTICITY (sep-TIS-it-tee) SEPTICITY

Septicity is the condition in which organic matter decomposes to form foul-smelling products associated with the absence of free oxygen. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

STERILIZATION (stare-uh-luh ZAY-shun) STERILIZATION

The removal or destruction of all living microorganisms, including pathogenic and saprophytic bacteria, vegetative forms and spores. Compare with DISINFECTION.

TITRATE (TIE-trate) TITRATE

To *TITRATE* a sample, a chemical solution of known strength is added on a drop-by-drop basis until a color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical solution to completion of the reaction as signaled by the end point.

TOTAL RESIDUAL CHLORINE TOTAL RESIDUAL CHLORINE

The amount of chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine. Also see RESIDUAL CHLORINE.

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 1 of 5 Lessons)

10.0 NEED FOR DISINFECTION

10.00 Effectiveness in Microorganism Removal by Various Treatment Processes

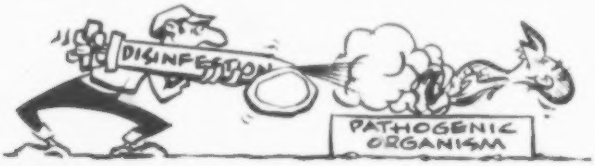
Homes, hospitals and industrial facilities all discharge liquid and solid waste materials into the wastewater collection system. Diseases from human discharges may be transmitted by wastewater. Typical disease-causing microorganisms include bacteria, viruses, and parasites. These microorganisms are commonly referred to as *PATHOGENIC* (disease-causing) *ORGANISMS*.[1] These microorganisms can cause the following types of illnesses:

Bacteria-caused:
Salmonellosis
Shigellosis
Typhoid Fever
Cholera
Paratyphoid
Bacillary Dysentery

Virus-caused:
Polio
Infectious Hepatitis

Internal Parasite-caused:
Amoebic Dysentery
Ascaris (giant roundworm)
Giardiasis

Disease-producing microorganisms are potentially present in all wastewaters. These microorganisms must be removed or killed before treated wastewater can be discharged to the receiving waters. The purpose of disinfection is to destroy pathogenic microorganisms and thus prevent the spread of waterborne diseases.



Wastewater treatment processes usually remove some of the pathogenic microorganisms through the following processes:

1. Physical removal through sedimentation and filtration,
2. Natural die-away of microorganisms in an unfavorable environment, and
3. Destruction by chemicals introduced for treatment purposes.

Effectiveness of treatment processes in removing microorganisms depends on the type of treatment processes and the hydraulic and organic loadings. Typical removals by various processes are summarized below:

Treatment Process	Microorganism Removal, %
Screening	10-20
Grit Channel	10-25
Primary Sedimentation	25-75
Chemical Precipitation	40-99+
Trickling Filters	90-95
Activated Sludge	90-98

Although pathogenic microorganisms are reduced in number by the various treatment processes listed and by natural die-away in unfavorable environments by storage, many microorganisms still remain. To insure that essentially all pathogenic microorganisms are destroyed in the effluents of wastewater treatment plants, disinfection is practiced. Since chlorine is the most widely used chemical for disinfection, this chapter will deal primarily with the principles and practices of chlorine disinfection (Fig. 10.1).

10.01 Disinfection

Two terms you should understand are "disinfection" and "sterilization." *DISINFECTION* is the destruction of all pathogenic microorganisms, while *STERILIZATION* is the destruction of all microorganisms.

The main objective of disinfection is to prevent the spread of disease by protecting:

1. Public water supplies,
2. Receiving waters for recreational uses, and
3. Shellfish growing areas.

Disinfection is effective because pathogenic microorganisms are more sensitive to destruction by chlorination than nonpathogens. Many nonpathogenic microorganisms are classified as *SAPROPHYTES*[2] and are essential to wastewater treatment processes. Chlorination for disinfection purposes results in killing essentially all of the pathogens in the plant effluent. No attempt is made to *STERILIZE* wastewater because it is unnecessary and impractical. Many other sensitive organisms in contact with chlorine are destroyed too. Chlorine is a nonselective killer. Organisms are affected by chlorine on the basis of their sensitivity and growth rate and also on the concentration of chlorine and exposure time.

---

[1] *Pathogenic (path-o-JEN-nick) Organisms. Bacteria, viruses or cysts which can cause disease (typhoid, cholera, dysentery). There are many types of bacteria which do* NOT *cause disease and which are* NOT *called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.*

[2] *Saprophytes (SAP-pro-fights). Organisms living on dead or decaying organic matter. They help natural decomposition of the organic solids in wastewater.*

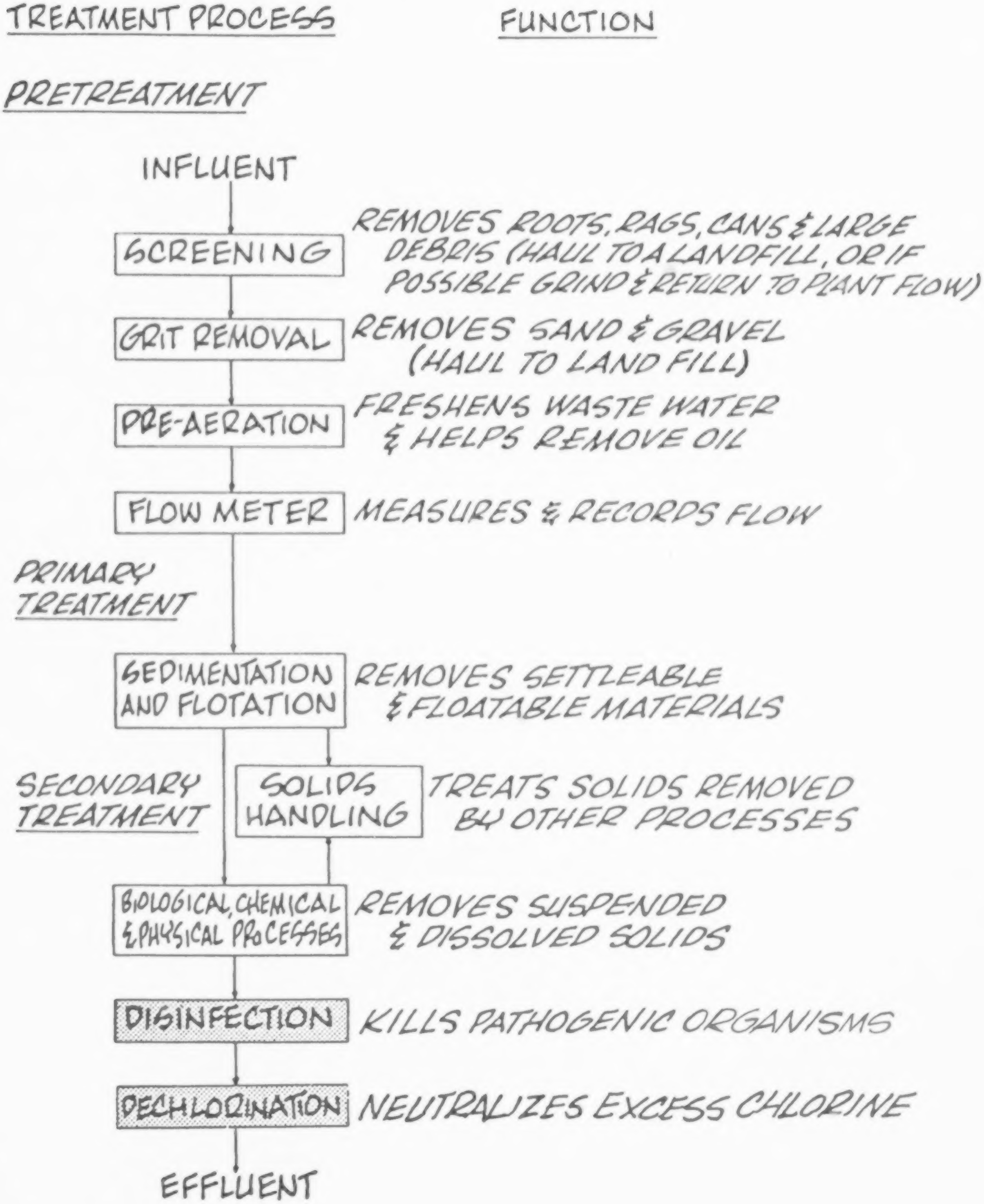

TREATMENT PROCESS
FUNCTION
PRETREATMENT
INFLUENT
SCREENING
REMOVES ROOTS, RAGS, CANS & LARGE DEBRIS (HAUL TO A LANDFILL, OR IF POSSIBLE GRIND & RETURN TO PLANT FLOW)
GRIT REMOVAL
REMOVES SAND & GRAVEL (HAUL TO LAND FILL)
PRE-AERATION
FRESHENS WASTE WATER & HELPS REMOVE OIL
FLOW METER
MEASURES & RECORDS FLOW
PRIMARY TREATMENT
SEDIMENTATION AND FLOTATION
REMOVES SETTLEABLE & FLOATABLE MATERIALS
SECONDARY TREATMENT
SOLIDS HANDLING
TREATS SOLIDS REMOVED BY OTHER PROCESSES
BIOLOGICAL, CHEMICAL & PHYSICAL PROCESSES
REMOVES SUSPENDED & DISSOLVED SOLIDS
DISINFECTION
KILLS PATHOGENIC ORGANISMS
DECHLORINATION
NEUTRALIZES EXCESS CHLORINE
EFFLUENT

Fig. 10.1 Typical flow diagram of wastewater treatment plant

One of the main uses of chlorine in wastewater treatment is for disinfection. Chlorine is relatively easy to obtain and cheap to manufacture. Even at relatively low dosages, chlorine is extremely effective.

Today people are living more intimately with wastewater than ever before. Wastewater effluent may be used for irrigating lawns, parks, cemeteries, freeway planting, golf courses, college campuses, athletic fields, and other public areas. Recreational lakes used for boating, swimming, water skiing, fishing, and other water sports are frequently made up partially and, in a few cases, solely of treated effluents. As public contact has increased and diluting waters have decreased or become of poor quality, it has become obvious that more consideration must be given to disinfection practices.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

10.0A What is the purpose of disinfection? Why is this important?

10.0B How are pathogenic bacteria destroyed or removed from water?

10.0C Why is chlorination used for disinfection?

10.0D Why are wastes not sterilized?

10.02 Reaction of Chlorine in Wastewater

Chlorine is applied to wastewater as *FREE CHLORINE*[3] (Cl_2), as *HYPOCHLORITE*[4] ion (OCl^-), or as chlorine dioxide (ClO_2). In either the free chlorine or hypochlorite ion form, chlorine is an extremely active chemical and acts as a potent *OXIDIZING AGENT.*[5] In the chlorine dioxide form, chlorine is not as potent an oxidizing agent in the pH ranges commonly found in most wastewaters. Since chlorine is very reactive, it is often used up by side reactions before disinfection takes place. These side reactions can be with such substances as organic material, hydrogen sulfide, phenols, thiosulfate, and ferrous iron. These side reactions occur first and use up a major portion of the chlorine necessary to meet the *CHLORINE DEMAND*[6] for a wastewater.

10.020 Free Chlorine (Cl_2)

Free chlorine combines with water to form hypochlorous and hydrochloric acids:

$$\text{Chlorine} + \text{Water} \rightleftharpoons \begin{matrix}\text{Hypochlorous}\\ \text{Acid}\end{matrix} + \begin{matrix}\text{Hydrochloric}\\ \text{Acid}\end{matrix}$$

$$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$$

In solutions that are dilute and have a pH above 4, the formation of HOCl (hypochlorous acid) is most complete and leaves little Cl_2 existing. The hypochlorous acid is a weak acid and is very poorly dissociated (broken up) at levels below a pH of 6. Thus any free chlorine or hypochlorite (OCl^-) added to water will immediately form either HOCl or OCl^- and what will be formed is controlled by the pH value of the water. This is extremely important since HOCl and OCl^- differ in disinfection ability. HOCl has a greater disinfection potential than OCl^-. Normally in wastewater with a pH of 7.3 (depends on temperature), 50 percent of the chlorine present will be in the form of HOCl and 50 percent in the form of OCl^-. The higher the pH level, the greater the percent of OCl^-.

10.021 Hypochlorite (OCl^-)

When hypochlorite compounds are used in wastewater, they are usually in the form of sodium hypochlorite (NaOCl). Calcium hypochlorite ($Ca(OCl)_2$) normally is not used because of its cost, sludge-forming characteristics and explosive nature.

The use of hypochlorite in wastewater follows the reaction similar to that of chlorine gas.

$$\begin{matrix}\text{Sodium}\\ \text{Hypochlorite}\end{matrix} + \text{Water} \rightarrow \begin{matrix}\text{Sodium}\\ \text{Hydroxide}\end{matrix} + \begin{matrix}\text{Hypochlorous}\\ \text{Acid}\end{matrix} + \begin{matrix}\text{Hypochlorite}\\ \text{Ion}\end{matrix} + \begin{matrix}\text{Hydrogen}\\ \text{Ion}\end{matrix}$$

$$2\ NaOCl + 2H_2O \rightarrow 2\ NaOH + HOCl + OCl^- + H^+$$

The difference between chlorine gas and hypochlorite compounds is in the side reactions formed. The reaction of chlorine gas tends to decrease the pH which favors the HOCl (hypochlorous acid) formation while the hypochlorite increases the pH with the formation of hydroxyl ions (OH^-) by the formation of sodium hydroxide. At a high pH of around 10, the hypochlorous acid (HOCl) dissociates.

$$\begin{matrix}\text{Hypochlorous}\\ \text{Acid}\end{matrix} \rightleftharpoons \begin{matrix}\text{Hydrogen}\\ \text{Ion}\end{matrix} + \begin{matrix}\text{Hypochlorite}\\ \text{Ion}\end{matrix}$$

$$HOCl \rightleftharpoons H^+ + OCl^-$$

This pH condition lasts only a brief time at the contact of the hypochlorite solution and the wastewater to be treated. Since the hypochlorite ion (OCl^-) is a relatively ineffective disinfectant, the sodium hypochlorite solution should be as dilute as possible. This is extremely important in wastewater disinfection.

---

[3] *Free Chlorine. Free chlorine is chlorine (Cl_2) in a liquid or gaseous form. Free chlorine combines with water to form hypochlorous (HOCl) and hydrochloric (HCl) acids. In wastewater free chlorine usually combines with an amine (ammonia or nitrogen) or other organic compounds to form combined chlorine compounds.*

[4] *Hypochlorite (hi-poe-KLOR-ite). Hypochlorite compounds contain chlorine and are used for disinfection. These compounds are similar to a strong bleach. They are available as liquids or solids (powder, granules, and pellets) in barrels, drums and cans.*

[5] *Oxidizing Agent. An oxidizing agent is any substance, such as oxygen (O_2) and chlorine (Cl_2), that can add (take on) electrons. When oxygen or chlorine is added to wastewater, organic substances are oxidized. These oxidized organic substances are more stable and less likely to give off odors or to contain disease bacteria. The opposite of REDUCING AGENT.*

[6] *Chlorine Demand. Chlorine demand is the difference between the amount of chlorine added to wastewater and the amount of* RESIDUAL CHLORINE[7] *remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of impurities in water. Chlorine Demand, mg/L = Chlorine Applied, mg/L − Chlorine Residual, mg/L.*

[7] *Residual Chlorine. Residual chlorine is the amount of chlorine remaining after a given contact time and under specified conditions.*

10.022 Chlorine Dioxide (ClO_2)

Chlorine dioxide reacts in the following manner:

Chlorine Dioxide + Water → Chlorate Ion + Chlorite Ion + Hydrogen Ions

$$2\ ClO_2 + H_2O \rightarrow ClO_3^- + ClO_2^- + 2H^+.$$

The oxidizing capability of chlorine dioxide is not all used in wastewater treatment because reactions with the substances (*REDUCING AGENTS*[8]) in wastewater only cause the reduction of chlorine dioxide to chlorite.

Chlorine Dioxide + Electron = Chlorite Ion

$$ClO_2 + e^- = ClO_2^-$$

Therefore, chlorine dioxide is not as reactive as chlorine and chlorine is a better oxidant. In waters with a pH above 8.5, chlorine dioxide is a very effective disinfectant. Chlorine dioxide usually does not react with ammonia.

Chlorine dioxide is very unstable and must be generated at the plant site. Generally chlorine dioxide is prepared by the injection of sodium chlorite into the chlorine solution line from a chlorinator.

Sodium Chlorite + Chlorine → Sodium Chloride + Chlorine Dioxide

$$2\ NaClO_2 + Cl_2 \rightarrow 2\ NaCl + 2\ ClO_2$$

Chlorine dioxide may find more applications in the water treatment field than in wastewater treatment because chlorine dioxide is less likely than chlorine to produce cancer-causing compounds and to cause tastes and odors in water.

10.03 Reactions of Chlorine Solutions with Impurities in Wastewater

Since wastewater contains a great number of complex substances and chemicals, many of these substances have a serious effect on wastewater chlorination. A few of the major impurities will be discussed in the following sections.

10.030 Inorganic Reducing Materials

Chlorine reacts rapidly with many reducing agents and more slowly with others. These reactions complicate the use of chlorine for disinfecting purposes. One of the most widely known inorganic reducing materials is hydrogen sulfide. Hydrogen sulfide reacts with chlorine to form sulfuric acid (sulfate) or elemental sulfur depending on the concentration of hydrogen sulfide, pH and temperature.

1. Hydrogen Sulfide + Free Chlorine + Water → Sulfuric Acid + Hydrochloric Acid

$$H_2S + 4\ Cl_2 + 4\ H_2O \rightarrow H_2SO_4 + 8\ HCl$$

2. Water + Free Chlorine → Hypochlorous Acid + Hydrogen Sulfide → Elemental Sulfur + Hydrochloric Acid + Water

$$H_2O + Cl_2 \rightarrow HOCl + H_2S \rightarrow \underset{\downarrow}{S^\circ} + HCl + H_2O$$

One part of hydrogen sulfide (H_2S) takes about 8.5 parts of chlorine in equation 1 and 2.2 parts of chlorine in equation 2. Since these reactions occur before a chlorine residual occurs, the demand caused by the inorganic salts must be satisfied first before any disinfection can take place. Ferrous iron, manganese, and nitrite are examples of other inorganic reducing agents that react with chlorine.

10.031 Reaction with Ammonia (NH_3)

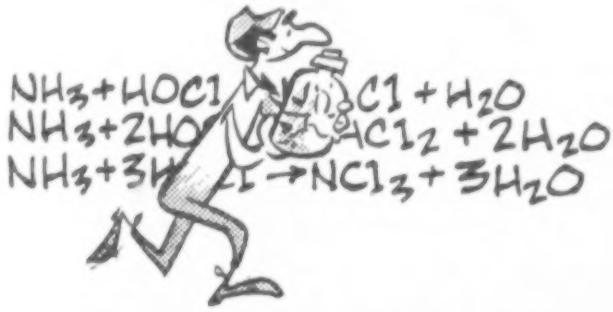
Since ammonia is present in all domestic wastewaters, the reaction of ammonia with chlorine is of great significance. When chlorine is added to waters containing ammonia, the ammonia reacts with hypochlorous acid (HOCl) to form monochloramine, dichloramine and trichloramine. The formation of these chloramines depends on the pH of the solution and the initial chlorine-ammonia ratio.

Ammonia + Hypochlorous Acid → Chloramine + Water

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$	monochloramine
$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$	dichloramine
$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$	trichloramine

In general at the pH levels that are usually found in wastewater (pH 6.5 to 7.5), monochloramine and dichloramine exist together. At pH levels below 5.5, dichloramine exists by itself. Below pH 4.0, trichloramine is the only compound found.

The mono- and dichloramine forms have definite disinfection powers and are of interest in the measurement of chlorine residuals. Dichloramine has a more effective disinfecting power than monochloramine.



If enough chlorine is added to react with the inorganic compounds and *NITROGENOUS*[9] compounds, then this chlorine will react with organic matter to produce *CHLORORGANIC*[10] compounds or other combined forms of chlorine, which have slight disinfecting action. Then if enough chlorine

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[8] Reducing Agent. A reducing agent is any substance, such as the chloride ion (Cl^-) and the sulfide ion (S^{-2}), that can give up electrons. The opposite of OXIDIZING AGENT.

[9] Nitrogenous (nye-TROG-en-ous). Nitrogenous compounds contain nitrogen.

[10] Chlororganic (chlor-or-GAN-nick). Chlororganic compounds are organic compounds combined with chlorine. These compounds generally originate from, or are associated with, living or dead organic materials.

is added to react with all the above compounds, any additional chlorine will exist as *FREE AVAILABLE CHLORINE*[11] which has the highest disinfecting action (Fig. 10.2). This situation rarely exists in wastewater that contains nitrogenous compounds. The term *BREAKPOINT CHLORINATION*[12] refers to the breakpoint shown on Fig. 10.2.

The exact mechanism of this disinfection action is not fully known. In some theories, chlorine is considered to exert a direct action against the bacterial cell, thus destroying it. Another theory is that the toxic character of chlorine inactivates the *ENZYMES*[13] upon which the living microorganisms are dependent for utilizing their food supply. As a result, the organisms die of starvation. From the point of view of wastewater treatment, the mechanism of the action of chlorine is much less important than its effects as a disinfecting agent.

The demand by inorganic and organic materials is referred to as "chlorine demand." The chlorine that remains in combined forms having disinfecting properties plus any free chlorine is referred to as "residual chlorine." The sum of the chlorine demand and the chlorine residual is the chlorine dose.

Chlorine Dose = Chlorine Demand + Chlorine Residual

where

Chlorine Residual = Combined Chlorine Forms + Free Chlorine

10.04 Hypochlorination[14] of Wastewater

Hypochlorination is usually not the most common method of disinfection. Higher costs and the disinfecting deficiencies of hypochlorination make chlorination the most effective method in most cases. Some cities recently have switched to hypochlorination for safety reasons because chlorine gas is not involved. As previously described, when the pH is increased, the hypochlorite ion (OCl^-) formation is increased and is less efficient than the hypochlorous acid ($HOCl$). However, when the hypochlorite solution is added to wastewater, the solution becomes diluted with the pH usually approaching that of the wastewater.

Hypochlorination will raise the pH of the wastewater being treated. The rise in pH will decrease the effectiveness of the hypochlorite, thereby requiring a higher dosage. This, in turn, will increase the pH even more.

10.05 Factors Influencing Disinfection

Both *CHLORINE ADDITION* and *CONTACT TIME* are essential for effective killing of pathogenic microorganisms. Experimental determination of the best combination of combined residual chlorine and contact time is necessary to insure both proper chlorine dose and minimum use of chlorine. Changes in pH affect the disinfection ability of chlorine and the operator must reexamine the best combination of chlorine addition and contact time when the pH fluctuates. Critical factors influencing disinfection are summarized as follows:

1. Injection point and method of mixing to get disinfectant in contact with wastewater being disinfected.
2. Design (shape) of contact chambers are designed in various sizes and shapes. Rectangular contact chambers often allow short-circuiting and consequently reduced contact times. Baffles often are installed to increase mixing action, to obtain better distribution of disinfectant, and to reduce short-circuiting which in turn increases contact time. Pipelines have proved to be good contact chambers.
3. Contact time. With good initial mixing, the longer the contact time, the better the disinfection. Most chlorine contact basins are designed to provide a contact time of 30 minutes. In general, extending the chlorine contact time is more effective than increasing the chlorine dose to improve disinfection.
4. Effectiveness of upstream treatment processes. The lower the suspended solids and organic content of the wastewater, the better the disinfection.
5. Temperature. The higher the temperature, the more rapid the rate of disinfection.
6. Dose rate and type of chemical. Normally the higher the dose rate, the quicker the disinfection rate. The form or type of chemical also influences the disinfection rate.
7. pH. The lower the pH, the better the disinfection.

10.06 Chlorine Requirements

The quantity of chlorine-demanding substances differs from plant to plant, so that the amount of chlorine that has to be added to insure proper disinfection also differs. The amount of chlorine required to satisfy the chlorine-demanding substances is called the *CHLORINE DEMAND*. This demand is equal to the chlorine dose minus the chlorine residual.

Chlorine Demand = Chlorine Dose − Chlorine Residual

The chlorine residual is determined by one of several laboratory tests. The method of choice must be one of those approved by state and federal water pollution control agencies, otherwise the results will not be recognized. These tests are discussed in the laboratory section of this manual (Chapter 16). The amount of residual that one should maintain is determined by the desired microorganism population. The microorganism population is usually specified by State or Federal NPDES Permit requirements. The microorganism population usually is estimated by determining the *MPN*[15] of *COLIFORM*[16] -group organisms present. This determination does not test for individual pathogenic microorganisms, but uses the coliform group of organisms as the indicator organism. Coliform organisms usually are found in most wastewaters. See Chapter 16 for the laboratory test to determine the MPN of coliforms present.

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[11] *Free Available Chlorine. The amount of chlorine available in water. This chlorine may be in the form of dissolved gas (Cl_2), hypochlorous acid ($HOCl$), or hypochlorite (OCl^-), but does not include chlorine combined with an amine (ammonia or nitrogen) or other organic compound.*

[12] *Breakpoint Chlorination. Addition of chlorine to water or wastewater until the chlorine demand has been satisfied and further additions of chlorine result in a residual that is directly proportional to the amount added beyond the breakpoint.*

[13] *Enzymes (EN-zimes). Enzymes are organic substances which are produced by living organisms and speed up chemical changes.*

[14] *Hypochlorination (hi-po-KLOR-i-NAY-shun). The application of hypochlorite compounds to water or wastewater for the purpose of disinfection.*

[15] *MPN (EM-PEA-EN). MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume. Expressed as density or population of organisms per 100 ml.*

[16] *Coliform (COAL-i-form). One type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes other environmental sources.*

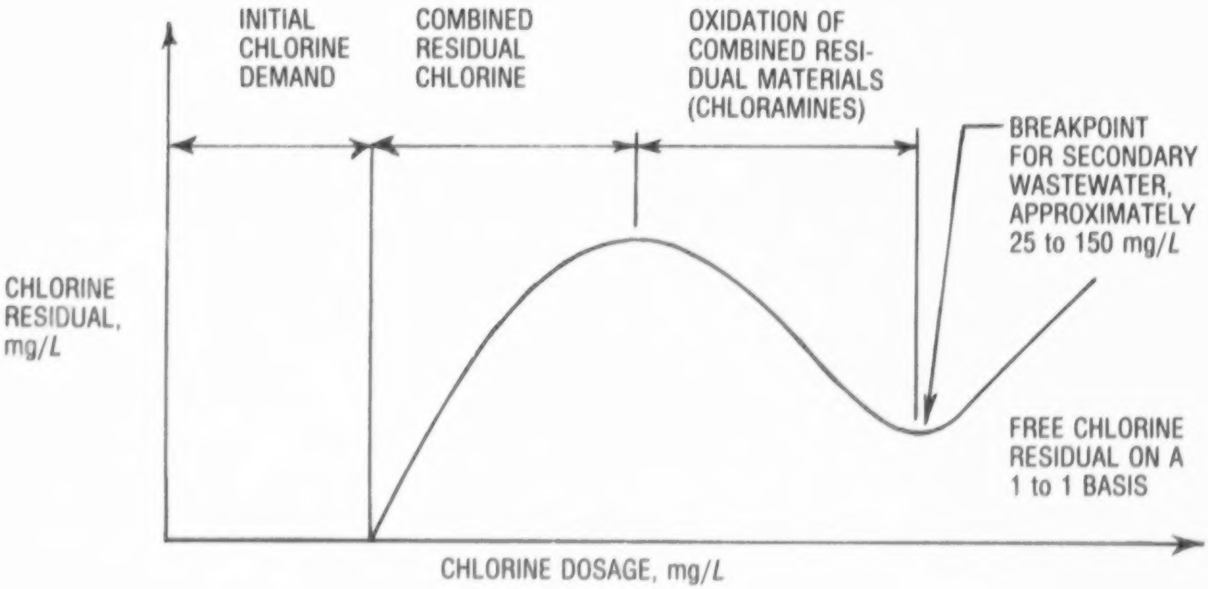

INITIAL CHLORINE DEMAND
COMBINED RESIDUAL CHLORINE
OXIDATION OF COMBINED RESIDUAL MATERIALS (CHLORAMINES)
BREAKPOINT FOR SECONDARY WASTEWATER, APPROXIMATELY 25 to 150 mg/L
CHLORINE RESIDUAL, mg/L
FREE CHLORINE RESIDUAL ON A 1 to 1 BASIS
CHLORINE DOSAGE, mg/L

Fig. 10.2 Breakpoint chlorination curve

Calculations to determine the chlorine dosage and chlorine demand are illustrated in the following example problem.

EXAMPLE:

A chlorinator is set to feed 50 pounds of chlorine per 24 hours; the wastewater flow is at a rate of 0.85 MGD, and the chlorine as measured by the chlorine residual test after thirty minutes of contact time is 0.5 mg/*L*. Find the chlorine dosage and chlorine demand in mg/*L*.

$$\text{Chlorine Feed or Dose, mg}/L = \frac{\text{Pounds of Chlorine}}{\text{Million Pounds of Water}}$$

$$= \frac{50\text{ lbs chlorine/day}}{(0.85\text{ MG/day})\ (8.34\text{ lbs/gal})}$$

$$= \frac{59\text{ lbs chlorine/MG}}{8.34\text{ lbs/gal}}$$

```
       59.
0.85)50.00
     42 5
      7 50
      7 65
```

$$= 7.1\text{ lbs chlorine/million pounds water}$$

$$= 7.1\text{ ppm (Parts Per Million parts)}$$

$$= 7.1\text{ mg}/L$$

$$\text{Chlorine Demand, mg}/L = \text{Chlorine Dose, mg}/L - \text{Chlorine Residual, mg}/L$$

$$= 7.1\text{ mg}/L - 0.5\text{ mg}/L$$

$$= 6.6\text{ mg}/L$$

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

10.0E What does chlorine produce when it reacts with organic matter and with nitrogenous compounds?

10.0F How much chlorine must be added to wastewater to produce disinfecting action?

10.0G How is the chlorine demand determined?

10.0H How is the chlorine dosage determined?

10.0I Calculate the chlorine demand of treated domestic wastewater if:

Flow Rate = 1.2 MGD
Chlorinator = 70 lbs of chlorine per 24 hours
Residual = 0.4 mg/*L* after thirty minutes

The objective of disinfection is the destruction of pathogenic bacteria, and the ultimate measure of the effectiveness is the bacteriological result. The measurement of residual chlorine does supply a tool for practical control. If the residual chlorine value commonly effective in most wastewater treatment plants does not yield satisfactory bacteriological kills in a particular plant, the residual chlorine that does must be determined and used as a control in that plant. In other words, the 0.5 mg/*L* residual chlorine, while generally effective, is not a rigid standard but a guide that may be changed to meet local requirements.

One special case would be the use of chlorine in the effluent from a plant serving a tuberculosis hospital. Studies have shown that a residual of at least 2.0 mg/*L* should be maintained in the effluent from this type of institution, and that detention time should be at least two hours at the average rate of flow instead of the thirty minutes which is normally used for basis of design. Two-stage chlorination may be particularly effective in this case.

The following list of chlorine dosages provides a reasonable guideline to produce chlorine residual adequate for applications indicated for domestic wastewaters. Individual plants may require higher or lower dosages, depending upon type and amount of suspended and dissolved organic compounds in the chlorinated sample.

APPLICATION	DOSAGE RANGE, mg/L
Collection Systems	
Slime Control	1-15
Corrosion Control	10-25
Odor Control	10-25
Treatment	
Grease Removal	1-10
BOD Reduction	1-10
Inorganic Compounds	2-12
Filter Ponding	1-10
Filter Flies	0.5
Activated Sludge	
Bulking	1-10
Digester	
Supernatant	20-150
Foaming	2-20
Disinfection	
Raw Wastewater	10-30
Primary-Clarifier Effluent	5-20
Chemical Precipitation	2-6
Trickling-Filter Effluent*	3-20
Activated-Sludge Effluent*	2-8
Advanced Waste Treatment	1-5

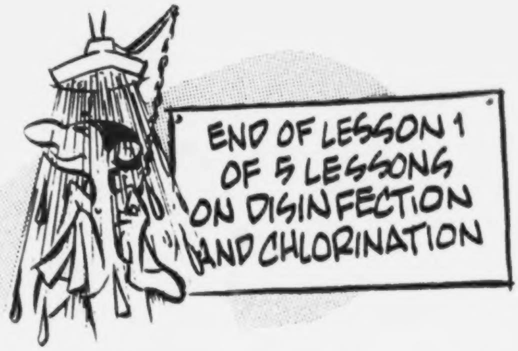
*After secondary clarification

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

10.0J What is the objective of disinfection?

10.0K How is the effectiveness of the chlorination process for a particular plant determined?



Please answer the discussion and review questions before continuing with Lesson 2.

DISCUSSION AND REVIEW QUESTIONS

Chapter 10. DISINFECTION AND CHLORINATION

(Lesson 1 of 5 Lessons)

At the end of each lesson in this chapter, you will find discussion and review questions that you should work before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson.

Write the answers to these questions in your notebook before continuing.

1. Why must wastewaters be disinfected?
2. Why is chlorination used to disinfect wastewater?
3. To improve disinfection, which is more effective — increasing the chlorine dose, or extending the chlorine contact time?
4. What constituents in wastewater are mainly responsible for the chlorine demand?
5. Calculate the chlorinator setting (lbs per 24 hours) to treat a waste with a chlorine demand of 12 mg/*L*, when a chlorine residual of 2 mg/*L* is desired, if the flow is 1 MGD.
6. How do suspended and dissolved organic compounds in an effluent affect disinfection?

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 2 of 5 Lessons)

10.1 POINTS OF CHLORINE APPLICATION (Fig. 10.3)

10.10 Collection System Chlorination

One of the primary benefits of up-sewer chlorination is to prevent the deterioration of structures. Other benefits include odor and septicity control, and possibly BOD reduction to decrease the load imposed on the wastewater treatment processes. In some instances, the maximum benefit may result from a single application of chlorine at a point on the main intercepting sewer before the junction of all feeder sewer lines. In others, several applications at more than one point on the main intercepting sewer or at the upper ends of the feeder lines may prove most effective. Due to high costs *CHLORINATION SHOULD BE CONSIDERED AS A TEMPORARY OR EMERGENCY MEASURE IN MOST CASES,* with emphasis being placed on proper design of the system. Aeration also is effective in controlling septic conditions in collection systems. Although many problems result from improper design or design for future capacity requirements, the need for hydrogen sulfide protection exists under the best of conditions in some locations.

10.11 Prechlorination

"Prechlorination" is defined as the addition of chlorine to wastewater at the entrance to the treatment plant, ahead of settling units and prior to the addition of other chemicals. In addition to its application for aiding disinfection and odor control at this point, prechlorination is applied to reduce plant BOD load, as an aid to settling, to control foaming in Imhoff units, and to help remove oil. Current trends are away from prechlorination to up-sewer aeration or other chemical treatment for control of odors.

10.12 Plant Chlorination

Chlorine is added to wastewater during treatment by other processes, and the specific point of application is related to the results desired. The purpose of plant chlorination may be for control and prevention of odors, corrosion, sludge bulking, digester foaming, filter ponding, filter flies, and as an aid in sludge thickening. Here again, chlorination should be an emergency measure. Extreme care must be exercised when applying chlorine because it can interfere with or inhibit biological treatment processes.

10.13 Chlorination Before Filtration

More stringent discharge requirements are causing many agencies to provide filtration for solids removal before discharge (Chapter 23). The better designs provide a means of chlorinating the water before application to the filters to kill algae and other large biological organisms. Prechlorination tends to prevent the development of biological growths which might cause short-circuiting or excessive backwashing in the filter media. Postchlorination of the effluent from the filter would be in addition to this application.

10.14 Postchlorination

"Postchlorination" is defined as the addition of chlorine to municipal or industrial wastewater following other treatment processes. This point of application should be before a *CHLORINE CONTACT UNIT*[17] and after the final settling unit in the treatment plant. The most effective place for chlorine application for disinfection is after treatment and on a well-clarified effluent. Postchlorination is used primarily for disinfection. As a result of chlorination for disinfection, some reduction in BOD

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[17] *Chlorine Contact Unit. A baffled basin that provides sufficient detention time for disinfection to occur.*

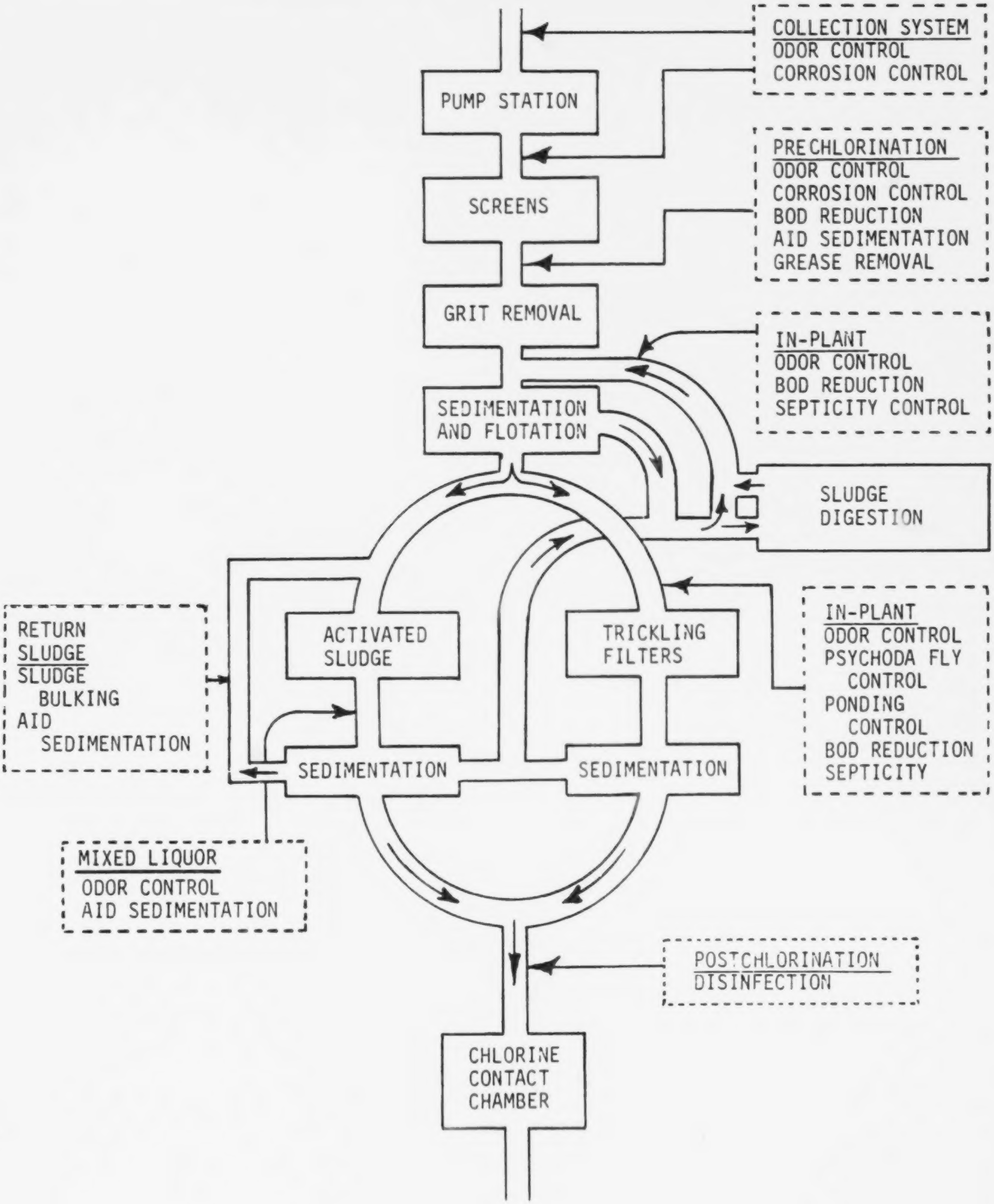
COLLECTION SYSTEM
ODOR CONTROL
CORROSION CONTROL
PUMP STATION
PRECHLORINATION
ODOR CONTROL
CORROSION CONTROL
BOD REDUCTION
AID SEDIMENTATION
GREASE REMOVAL
SCREENS
GRIT REMOVAL
IN-PLANT
ODOR CONTROL
BOD REDUCTION
SEPTICITY CONTROL
SEDIMENTATION AND FLOTATION
SLUDGE DIGESTION
RETURN SLUDGE
SLUDGE BULKING
AID SEDIMENTATION
ACTIVATED SLUDGE
TRICKLING FILTERS
IN-PLANT
ODOR CONTROL
PSYCHODA FLY CONTROL
PONDING CONTROL
BOD REDUCTION
SEPTICITY
SEDIMENTATION
SEDIMENTATION
MIXED LIQUOR
ODOR CONTROL
AID SEDIMENTATION
POSTCHLORINATION
DISINFECTION
CHLORINE CONTACT CHAMBER

Fig. 10.3 Points of chlorine application

may be observed; however, chlorination is rarely practiced solely for the purpose of BOD reduction.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

10.1A What is the purpose of up-sewer chlorination?

10.1B Where should chlorine be applied in sewers?

10.1C What are the main reasons for prechlorination?

10.1D Why might chlorine be added to wastewater during treatment by other processes?

10.1E What is the objective of postchlorination?

10.2 CHLORINATION PROCESS CONTROL

10.20 Chlorinator Control

The control of chlorine flow to points of application is accomplished by six basic methods and a seventh method which combines two of the basic six.

10.200 Manual Control

Feed-rate adjustment and starting and stopping of equipment is done by hand.

10.201 Start-Stop Control

Feed-rate adjustment by hand, starting and stopping (by interrupting injector water supply) controlled by starting of wastewater pump, flow switch, and level switch.

10.202 Step-Rate Control

Chlorinator feed rate is varied according to the number of wastewater pumps in service. As each pump starts, a pre-set quantity of chlorine is added to the flow of chlorine existing at starting time. This system can be applied conveniently with installations using up to eight pumps.

10.203 Time-Program Control

Chlorine feed rate is varied on a timed step-rate basis regulated to correspond to the times of flow changes or by using a time-pattern transmitter which uses a revolving cam cut to match a flow pattern.

10.204 Flow-Proportional Control

Chlorinator feed rate is controlled by a system which converts wastewater flow information into a chlorinator control valve. This can be accomplished by a variety of flow-metering equipment, including all process control instrumentation presently available and nearly all metering equipment now in use on wastewater systems.

10.205 Chlorine Residual Control

Chlorine feed rate is controlled to a desired chlorine residual (usually *COMBINED AVAILABLE CHLORINE*[18]) level. After mixing and reaction time (about five minutes maximum), a wastewater sample is *TITRATED*[19] by an *AMPEROMETRIC*[20] analyzer-recorder (or indicator). As the residual chlorine level varies above or below the desired (set point) level, the chlorinator is caused to change its feed rate to bring the chlorine residual back to the desired level.

10.206 Compound Loop Control

Any "automatic" control system (step-rate, timed program, flow proportional, or residual) can be employed in two ways: (1) by positioning the feed-rate valve; or (2) by varying the vacuum differential across the feed-rate valve. For instance, a flow-proportional (or step-rate, or timed program) control system may position the feed-rate valve, and a residual-control system may vary the vacuum differential across the feed-rate valve. Thus, changes in flow cause changes in feed-rate valve position, but changes in chlorine demand may occur without any flow change. When this happens, the residual analyzer detects a change in chlorine residual and, by varying the vacuum differential across the feed-rate valve, causes the chlorinator to change rates to meet the desired chlorine residual level.

Various combinations of compound loop control can be employed. Generally speaking, the part of the system requiring the fastest response should be applied to valve positioning (since it responds faster). If flow changes are rapid, flow control should be by valve position. If flow and demand change rates are nearly the same, the magnitude of change may dictate the selection of control.

The selection of control methods should be based on treatment costs and treatment results (required or desired). A waste discharger must normally meet a disinfection standard. A small treatment plant might do this with a compound loop control system costing several thousand dollars, but may save less than one hundred dollars a year in chlorine consumed. In this case the expense would not be justified. A manual system, which would meet the maximum requirements and overchlorinate at minimum requirement periods, might be used. It is not unheard of for a plant to have maximum chlorine residual requirements becaue of irrigation and/or marine life tolerances. In these cases the uncontrolled or haphazard application of chlorine cannot be considered, no matter how large the added cost.

A specified chlorine residual level may be required at some point downstream from the best residual control sample point. In this case a residual analyzer should be used to monitor and record residuals at this point. It may also be used to change the control set point of the controlling residual analyzer.

Ultimate control of dosage for disinfection rests on the results desired, that is, the bacterial level or concentration acceptable or permissible at the point of discharge. Determination of chlorine requirements according to the current edition of *STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER* is the best method of control. You must remember that the chlorine requirement or chlorine dose will vary with wastewater flow, time of contact, temperature, pH, and major waste constituents such as hydrogen sulfide, ammonia, and amount of dead and living organic matter.

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[18] *Combined Available Chlorine. The concentration of chlorine which is combined with ammonia (NH_3) as chloramine or as other chloro derivatives, yet is still available to oxidize organic matter.*

[19] *Titrate (TIE-trate). To* TITRATE *a sample, a chemical solution of known strength is added on a drop-by-drop basis until a color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical solution to completion of the reaction as signaled by the end point.*

[20] *Amperometric (am-PURR-o-MET-rick). A method of measurement that records electric current flowing or generated, rather than recording voltage. Amperometric titration is a means of measuring concentrations of certain substances in water.*

The chlorine requirements for various flow rates and contact times can be determined on either a plant or a laboratory scale. If the determination is made on a laboratory scale, you should expect the plant requirements to be somewhat higher. This is to be expected since the mixing and actual contact times can be more carefully controlled in the laboratory. It is preferable that the determinations be made by both methods and the results compared. If the chlorine requirement as determined by full plant tests is significantly greater than that determined by laboratory testing, a wastage of chlorine is indicated. The two major causes of a large discrepancy between laboratory and plant results are poor mixing at the point of chlorine injection and short-circuiting in the contact chamber. Either problem can usually be solved at a relatively small expense as compared to the savings which can be achieved by the reduced use of chlorine.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 389.

10.2A How can chlorine gas feed be controlled?

10.2B Control of chlorine dosage depends on the bacterial ____________ desired.

10.2C Define amperometric.

AMPEROMETRIC

10.21 Chlorination Control Nomogram[21]

Determination of the chlorine residual may give information that confirms the previous choice of dosage or indicates that the dosage should be readjusted. The contact period must be specified since longer contact periods increase chlorine uptake.

Since feed rate is expressed in pounds per day, the rate setting of the feeder must be calculated from determination of chlorine required and the flow. The simplest means of making the calculation is by a chlorination control nomogram taken from the *WPCF MANUAL OF PRACTICE NO. 11* (MOP 11), 1968 (Fig. 10.4). The following sequence is a guide to using this nomogram:

1. Lay a straightedge (ruler) on point on Line A, representing flow, and on point on Line B, representing *CHLORINE REQUIRED,*[22] and read point on Line C, which shows setting for chlorine feeder.
2. For any value in excess of maximum indicated on Scales A, B, or C, introduce proper factor of ten or multiple thereof. The application of a factor of ten will be presented later in Example 2.
3. Greatest accuracy will be obtained when the angle of the straightedge approaches a right angle with Line B. Multipliers of ten may be applied to aid in accomplishing this objective.
4. If straightedge does not cross all three scales, introduce necessary factors of ten and move straightedge to point where all three scales will be crossed.

Let's try some examples using Fig. 10.4. Assume the given chlorine dosage was selected on the basis of preliminary tests as capable of producing the desired results.

EXAMPLE 1

Given:	Maximum Flow Rate = 0.5 MGD
	Chlorine dosage = 1.0 mg/*L*
Procedure:	Place one end of straightedge (ruler) on 0.5 MGD (Line A) and draw a line through the point on Line B representing a chlorine dosage of 1.0 mg/*L*. Extend the line to Line C and read the point indicating the chlorine feed rate.
Answer:	Chlorine Feed Rate = 4.2 lbs per 24 hours

Check:

Chlorine Feed Rate = (Max. Flow, MGD) (Dosage, mg/*L*) (8.34 lbs/ gal)

$$= 0.5\,\frac{\text{MG}}{\text{day}} \times 1.0\,\frac{\text{mg}^{23}}{\text{M mg}} \times 8.34\,\frac{\text{lbs}}{\text{gal}} \qquad \begin{array}{r} 8.34 \\ 0.5 \\ \hline 4.170 \end{array}$$

= 4.17, say 4.2 lbs per day

EXAMPLE 2

Given:	Maximum Flow Rate = 5.0 MGD
	Chlorine Dosage = 1.0 mg/*L*
Procedure:	5.0 MGD is off our scale on Line A. Reduce flow by a factor of ten to 0.5 MGD, or 5.0 MGD/10 = 0.5 MGD. The problem is the same as Example 1, and the chart gives a chlorine feed rate of 4.2 lbs per 24 hrs. The flow rate is actually ten times 0.5 MGD (10 × 0.5 MGD = 5 MGD). Therefore the required chlorine feed rate is 10 × 4.2 lbs per 24 hours (10 × 4.2 = 42) or 42 lbs per 24 hours.
Note:	On a cold day, a 150-lb cylinder may not be adequate to provide this feed rate because the lines may freeze.

EXAMPLE 3

Given:	Maximum Flow Rate = 0.4 MGD
	Chlorine Dosage = 5.0 mg/*L*
Procedure:	A line through a flow of 0.4 MGD (Line A) and 5.0 mg/*L* (Line B) misses line C. The chlorine dosage should be reduced by a factor of ten to be able to use the nomogram.

---

[21] *Nomogram. A chart or diagram containing three or more scales used to solve problems with three or more variables instead of using mathematical formulas.*

[22] *Chlorine Requirement. The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or destroying some chemical in the water. In each case a definite chlorine dosage will be necessary. This dosage is the chlorine requirement.*

[23] *Recall concentrations in mg/L are the same as mg/M mg.*

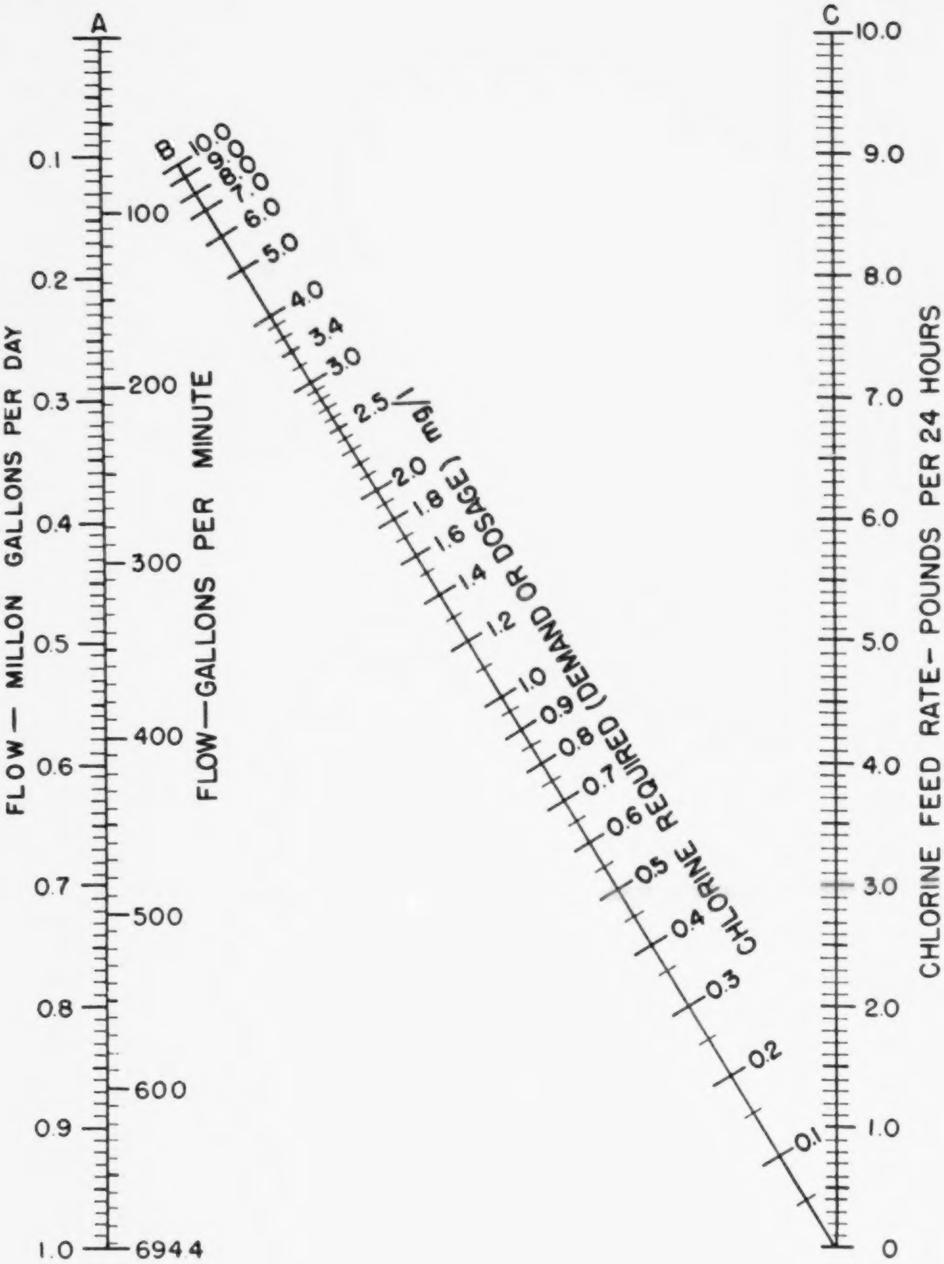

Fig. 10.4 Chlorination control nomogram

(Source: WPCF MOP No. 11, 1968)

$$\text{Chlorine Dosage} = \frac{5.0\text{ mg}/L}{10} = 0.5\text{ mg}/L$$

$$\begin{aligned}\text{Chlorine* Feed Rate} &= 1.7\text{ lbs per 24 hours (from chart)}\\ \text{Actual Feed Rate} &= (10)\ (1.7\text{ lbs per 24 hrs})\\ &= 17\text{ lbs per 24 hrs}\end{aligned}$$

The chlorine feed rate must be ten times the rate from the chart because the chlorine required was reduced by a factor of ten to use the chart.

The results from the chart should be checked using the mathematical calculations used in Example 1 to avoid errors. Note that the chlorine requirement should take into consideration the chlorine demand so that a desired residual is obtained after a given contact period. As discussed in Section 10.06, chlorine requirements vary with the wastewater characteristics, concentration, flow, and temperature. Adjustment of chlorine feeder rates to meet all these variations is the ultimate goal of good operation practice. More frequent adjustments are usually required for primary effluent than for secondary effluent.

Suggested schedule for adjusting manual-feeder rates:

1. In large plants — at least every hour,
2. In medium-sized plants — every two to four hours, and
3. In small plants — every eight hours.

Other methods of chlorinator control have been described in Section 10.20.

10.22 Hypochlorinator[24] Feed Rate and Control

Chlorine for disinfection and other purposes is provided in some plants by the use of hypochlorite compounds. The amount of chlorine delivered depends on the type of hypochlorite. For example, HTH (high test hypochlorite) contains 65 percent, by weight, of chlorine, and chlorinated lime contains 34 percent.

Manufacturers of hypochlorite compounds define available chlorine as the amount of gaseous chlorine required to make the equivalent hypochlorite chlorine. If you prepare a hypochlorite solution for disinfection and immediately measure the chlorine residual, you will find the chlorine residual about half of the expected value based on the manufacturer's amount of available chlorine. When hypochlorite is mixed with water, approximately half of the chlorine forms hydrochloric acid (HCl) and the other half forms hypochlorite (OCl^-), the chlorine residual that you measured.

EXAMPLE:

A wastewater requires a chlorine feed rate of 17 lbs per day. How many pounds of chlorinated lime will be required to provide the needed chlorine? Assume each pound of chlorinated lime contains 0.34 lbs of available chlorine.

$$\begin{aligned}\text{Chlorinated Lime Feed Rate, lbs/day} &= \frac{\text{Chlorine Required, lbs/day}}{\text{Portion of Chlorine in lb of Hypochlorite}}\\ &= \frac{17\text{ lbs/day}}{0.34}\\ &= 50\text{ lbs/day}\end{aligned}$$

Hypochlorinators can be installed on either small systems or large systems. Usually the larger systems use liquid chlorine because of lower costs. However, some very large cities use hypochlorite because it is safer. Treatment plants serving these cities are located in highly populated areas where escaping chlorine gas could threaten the lives of many people.

The items in feed systems of hypochlorinators and their construction are discussed below.

1. Some type of storage system for the solution. The storage container is made of corrosion-resistant materials such as plastic or other similar materials.
2. Solution piping which is usually fiber glass or PVC (polyvinyl chloride).
3. Diffusers that are made of the same material as the piping systems.
4. Valves and *EDUCTORS*[25] that are made of PVC.
5. Pumps that are made of corrosion-resistant materials.

   Epoxy-lined systems have been successful.
6. Flow meters. These meters can be constructed using a Hastelloy C straight-through metal tube *ROTAMETER*[26] with the float position determined magnetically and the flow rate transmitted either electrically or pneumatically.
7. Chlorine residual analyzers of the amperometric type are commonly installed.
8. Automatic controls that consist of a hypochlorite flow controller, recorder and totalizer, a ratio control station, and the necessary electronic signal converters.

The feed system can usually be operated automatically or by manual control. The operation of the hypochlorite system will usually require twice the cost of that of the liquid chlorine systems. Maintenance of the hypochlorinator system requires more operator-hours than do the liquid chlorine systems.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.2D How is the rate of dosage for a chlorinator determined?

10.2E Determine the chlorine feed rate, pounds per 24 hours, if you are treating:

1. A flow of 0.5 MGD and the chlorine required is 1.0 mg/*L*.
2. Flow = 0.8 MGD and chlorine required = 4.0 mg/*L*.
3. Flow = 6 MGD and chlorine required = 25 mg/*L*.

10.2F How frequently should feeder rates be adjusted with manual controls? Why?

10.2G How many pounds of HTH (high test hypochlorite) should be used per day by a hypochlorinator dosing a flow of 0.55 MGD at 12 mg/*L* of chlorine?

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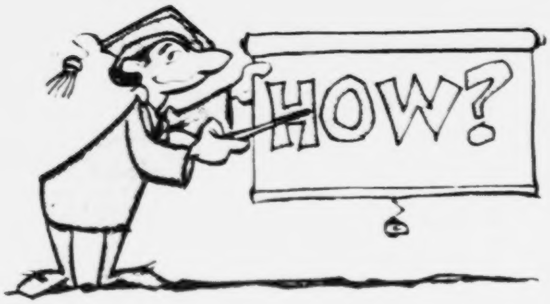
[24] *Hypochlorinator (hi-poe-KLOR-i-NAY-tor). A chlorine pump or device used to feed chlorine solutions made from hypochlorites such as bleach (sodium hypochlorite) or calcium hypochlorite.*

[25] *Eductor. A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump; sometimes used instead of a suction pump.*

[26] *Rotameter. A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.*



10.23 Chlorine Solution Discharge Lines, Diffusers, and Mixing

10.230 Solution Discharge Lines

Solution discharge lines are made from a variety of materials depending upon the requirements of service. Two primary requisites are that it must be resistant to the corrosive effects of chlorine solution and of adequate size to carry the required flows. Additional considerations are pressure conditions, flexibility (if required), resistance to external corrosion and stresses when underground or passing through structures, ease and tightness of connections, and the adaptability to field fabrication or alteration.

Development of plastics in the past several years has contributed greatly to chemical solution transmission. Polyvinyl chloride (PVC) pipe and black polyethylene flexible tubing have all but eliminated the use of rubber hose. Both are generally less expensive and both outlast rubber in normal service. The use of hose is almost exclusively limited to applications where flexibility is required or where extremely high back pressures exist.

PVC and polyethylene can be field fabricated and altered. PVC should be Schedule 80 to limit its tendency to cold flow and partially collapse under vacuum conditions, or for higher pressure ratings if required. Schedule 80 PVC may be threaded and assembled with ordinary pipe tools or may be installed using solvent-welded fittings.

Rubber-lined steel pipe has been used for many years where resistance to external stresses is required. It cannot be field fabricated or altered and is thus somewhat restricted in application. PVC lining of steel pipe has not yet become economically competitive, but other plastics, which can readily compete with rubber lining and are adaptable to field fabrication and alteration, have been developed.

Never use neoprene hose to carry chlorine solutions because it will become hard and brittle in a short time.

10.231 Chlorine Solution Diffusers

These diffusers are normally constructed of the same materials used for solution lines. Their design is an extremely important part of a chlorination program. This importance is almost completely related to the mixing of the chlorine solution with the wastewater being treated; however, strength and flexibility also must be given consideration. In most *CIRCULAR, FILLED* conduits flowing at 0.25 ft/sec (0.08 m/sec) or greater, a solution injected at the center of the pipeline will mix with the entire flow after flowing ten pipe diameters downstream. Mixing in open channels can be accomplished by the use of a hydraulic jump (Fig. 10.5) or by sizing diffuser orifices so that a high velocity (about 16 ft/sec or 4.8 m/sec) is attained at the diffuser discharge. This accomplishes two things: (1) introducing a pressure drop to get equal discharge from each orifice, and (2) imparting sufficient energy to the surrounding wastewater to complete the mixing. Generally speaking, a diffuser should be supplied for each two to three feet (0.6 to 1 meter) of channel depth. Diffusers should be placed across the width of the channel rather than in the direction of flow. Mixing also can be achieved by the use of high speed mechanical mixers specifically designed for this purpose.

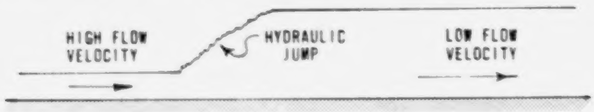


Fig. 10.5 Hydraulic jump

10.232 Mixing

Mixing as well as the speed of mixing are extremely important ahead of a chlorine contact tank or a residual sampling point. Since a contact tank is usually designed for low velocity, little mixing occurs after wastewater enters it. Mixing must be achieved before the contact tank is entered. The same is true for a chlorine residual sampling point. If good mixing does not occur somewhere upstream from the sampling point, erratic results will be obtained by the residual analyzing system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.2H Why does little mixing of the chlorine solution with wastewater occur in chlorine contact basins?

10.2I Chlorine solution discharge lines may be made of ____________ or ____________.

10.24 Measurement of Chlorine Residual

Refer to Chapter 16, "Laboratory Procedures and Chemistry," for procedures to measure chlorine residual. Amperometric titration provides for the most convenient, and the most repeatable results; however, the equipment costs are more expensive than for the other methods. The starch-iodide test can be used, but will have limited success in turbid or muddy waters. *DPD TESTS*[27] can be used and are less expensive than the other methods, but this also is a colorimetric method. The orthotolidine method is no longer a test that is recognized by federal agencies. Figure 10.6 shows a typical automatic chlorine residual analyzer.

10.25 Start-Up of Chlorinators

Before starting any chlorination system, read the plant Operation and Maintenance Manual and the manufacturer's literature to become familiar with the equipment. Review the plans or drawings of the facility. Determine what equipment, pipelines, pumps, tanks and valves are to be placed into service or are in service. The current status of the entire chlorination system must be known before starting or stopping any portion of the system. During emergencies you must act quickly and may not have time to check out each of the steps outlined above, but you still must follow established procedures.

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[27] *DPD Tests. A colorimetric chlorine residual test. DPD stands for N, N-diethyl-p-phenylenediamine.*

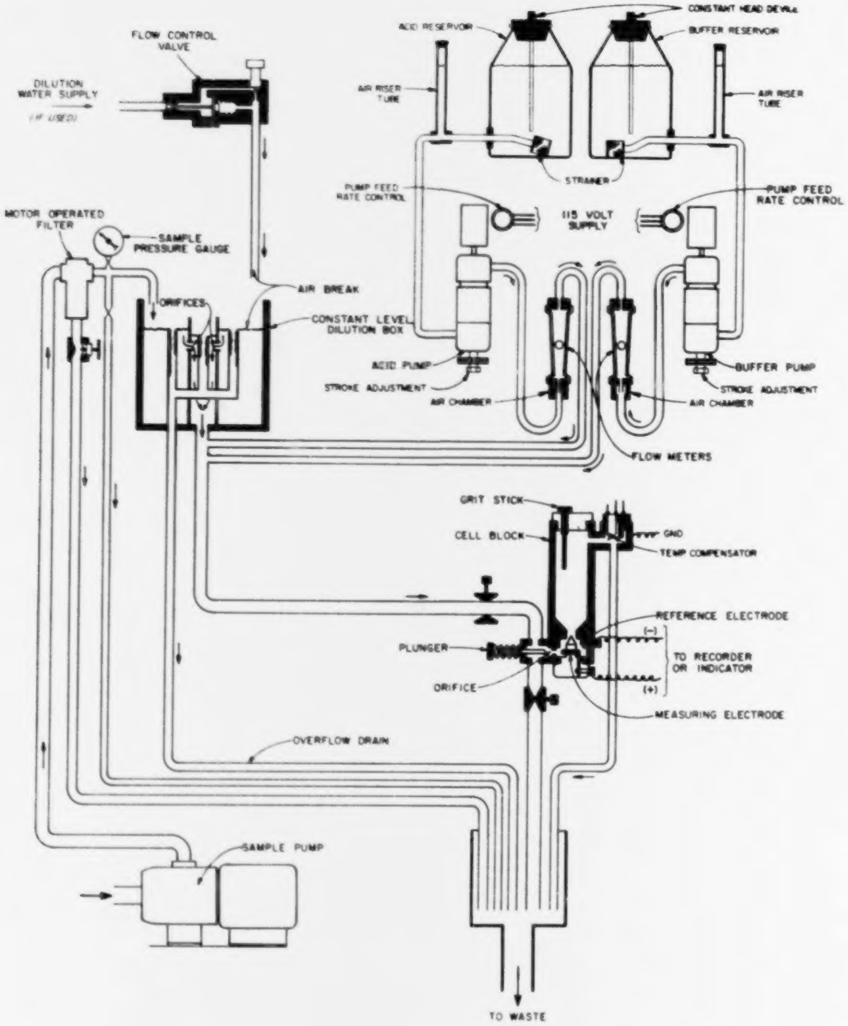
CONSTANT HEAD DEVICE
ACID RESERVOIR
BUFFER RESERVOIR
FLOW CONTROL VALVE
DILUTION WATER SUPPLY (IF USED)
AIR RISER TUBE
AIR RISER TUBE
STRAINER
PUMP FEED RATE CONTROL
PUMP FEED RATE CONTROL
115 VOLT SUPPLY
MOTOR OPERATED FILTER
SAMPLE PRESSURE GAUGE
AIR BREAK
ORIFICES
CONSTANT LEVEL DILUTION BOX
ACID PUMP
BUFFER PUMP
STROKE ADJUSTMENT
STROKE ADJUSTMENT
AIR CHAMBER
AIR CHAMBER
FLOW METERS
GRIT STICK
CELL BLOCK
GND
TEMP COMPENSATOR
REFERENCE ELECTRODE
(−)
PLUNGER
TO RECORDER OR INDICATOR
ORIFICE
(+)
MEASURING ELECTRODE
OVERFLOW DRAIN
SAMPLE PUMP
TO WASTE

Fig. 10.6 Automatic chlorine residual analyzer
(Permission of Wallace & Tiernan Division, Penwalt Corporation)

Procedures for start-up, operation, shutdown and troubleshooting are outlined in this section and are intended to be typical procedures for all types of chlorinators. For specific directions, see manufacturer's literature and plant O and M manual.

10.250 Gas Chlorinators

Start-up procedures for chlorinators using chlorine gas from containers are outlined in this section.

1. Be sure chlorine gas valve at the chlorinator is closed. This valve should have been closed since the chlorinator is out of service.
2. All chlorine valves on the supply line should have been closed during shutdown. Be sure they are still closed. If any valves are required to be open for any reason, this exception should be indicated by a tag on the valve.
3. Inspect all tubing, manifold and valve connections for potential leaks and be sure all joints are properly gasketed.
4. Check chlorine-solution distribution lines to be sure that system is properly valved to deliver chlorine solution to desired point of application.
5. Open chlorine metering orifice slightly by adjusting chlorine feed-rate control.
6. Start the injector water supply system. Usually the source of water is plant effluent (with a minimum of suspended solids) or potable water (after an *AIR-GAP*[28] or air-break system) supply. Injector water is pumped at an appropriate flow rate and the flow through the injector creates sufficient vacuum in the injector to draw chlorine. Chlorine is absorbed and mixed in the water at the injector. This chlorine solution is conveyed to the point of application.
7. Examine injector water supply system.
    a. Note reading of injector-supply pressure gage. If reading is abnormal (different from usual reading), try to identify cause and correct.
    b. Note reading of injector vacuum gage. If system does not have a vacuum gage, have one installed. If the vacuum reading is less than normal, the machine may function at a lower feed rate, but will be unable to deliver at rated capacity.
8. Inspect chlorinator vacuum lines for leaks.
9. Crack open the chlorine container valve and allow gas to enter the line. Inspect all joints for leaks by placing an ammonia-soaked rag near each joint. The formation of a white cloud or vapor will indicate a chlorine leak. Start with the valve at the chlorine container, move down the line and check all joints between this valve and the next one downstream. If the downstream valve passes the ammonia test, open the valve and continue to the next valve. If there are no leaks to the chlorinator, continue with the start-up procedure.
10. Inspect the chlorinator.
    a. Chlorine gas pressure at the chlorinator should be between 20 and 30 psi (1.4 to 2.1 kg/sq cm).
    b. Operate chlorinator at complete range of feed rates.
    c. Check operation on manual and automatic settings.
11. Chlorinator is ready for use. Log in the time the system is placed into operation and the application point.

10.251 Liquid Chlorine Chlorinators

Start-up procedures for chlorinators using liquid chlorine from containers are outlined in this section.

1. Inspect all joints, valves, manifolds and tubing connections in chlorination system, including application lines for proper fit and for leaks. Make sure that all joints have gaskets.
2. If chlorination system has been broken open or exposed to the atmosphere, verify that the system is dry. Usually once a system has been dried out, it is never opened again to the atmosphere. However, if moisture enters the system in the air or by any other means, it readily mixes with chlorine and forms hydrochloric acid which will corrode the pipes, valves, joints and fittings.

    To verify that the system is dry, determine the *DEW POINT*[29] (must be lower than 40°F or 5°C). If not dry, turn the evaporator on, pass dry air through the evaporator and force this air through the system. If this step is omitted and moisture is in the system, serious corrosion damage can result and the entire system may have to be repaired.
3. Start up the evaporators. Fill the water bath and adjust the device according to the manufacturer's directions.
4. Turn on the heaters on the evaporators.
5. Wait until the temperature of the evaporators reaches 180°F (82°C). This may take over an hour on large units.
6. Inspect and close all valves on the chlorine supply line.
7. Open the chlorine-metering orifice slightly. This is to prevent damage to the rotameter.
8. Start the injector water supply system.
9. Examine injector water supply system.
    a. Note reading of injector water supply pressure gage. If gage reading is abnormal (different than usual reading), try to identify the cause and correct it.

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[28] *Air Gap. An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the potable water. See Chapter 15, Section 15.2, paragraph 18, "Air-Gap Separation Systems."*

[29] *Dew Point Test. Dew point is the temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air. One way to measure the dew point is with a special dew point apparatus. This apparatus consists of a small box. The gas or air being tested enters the box on one side and leaves on the opposite side. One of the other sides has an observation window. A polished cup is inserted firmly in the top.*

Pass a sample of air or gas being tested through this apparatus. Adjust the flow so it can be felt against wetted lips, but not readily felt by the hand. Pour acetone into the cup. Allow the sample to pass through the cup for about five minutes. Add small amounts of crushed dry ice to the acetone. Stir continuously with a thermometer. Carefully add dry ice to the acetone as necessary to slowly lower the temperature. When dew or moisture first appears on the outside polished surface of the cup, read the temperature from the thermometer. This temperature is the DEW POINT. *The lower the dew point, the less moisture in the air. The amount of moisture in the air can be determined from a dew point temperature chart or table provided by manufacturers of dew point measuring equipment.*

   b. Note reading of injector vacuum gage. If system does not have a vacuum gage, have one installed. If the vacuum reading is less than normal, the machine may function at a lower feed rate, but will be unable to deliver at rated capacity.

10. Inspect chlorinator vacuum lines for leaks.
11. Close all valves on the supply line.
12. Crack open the *CHLORINE GAS LINE* at the chlorine container. All liquid chlorine systems should be checked by using gas because of the danger of leaks (gas is less dangerous). Inspect the joints between this valve and the next one downstream. If this valve passes the ammonia leak test, continue to the next valve down the line. Follow this procedure until the evaporator is reached. Before allowing chlorine to enter the evaporator and the chlorinator, make sure that all valves between the evaporator and the chlorinator are open. Heat in the evaporator will expand the gas, and if the system is closed, there could be problems. Chlorine should never be trapped in a line between the evaporator and the chlorinator.
13. If no problems develop, the gas line can be put in service by opening the valve 1½ to 2 turns.
14. Check the operation of the chlorinator.
    a. Operate over complete range of chlorine feed rates.
    b. Check operation on manual and automatic settings.
15. Inspect the liquid chlorine control valve. If OK, open the liquid chlorine control valve.
16. After admitting liquid chlorine to the system, wait until the temperature of the evaporator again reaches 180°F (82°C) and full working pressure (100 psi or 7 kg/sq cm). Inspect the evaporator by looking for leaks around pipe joints, unions and valves.
17. The system is ready for normal operation.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.2J What would you do before attempting to start any chlorination system?

10.2K How is the chlorination system inspected for leaks?

10.26 Normal and Abnormal Operation

Normal operation of the chlorination process requires regular observation of facilities and a regular preventive maintenance program. When something abnormal is observed or discovered, corrective action must be taken. This section outlines normal operation procedures and also responses to abnormal conditions.

10.260 Container Storage Area

Daily

1. Inspect building or area for ease of access by authorized personnel to perform routine and emergency duties.
2. Be sure fan and ventilation equipment are operating properly.
3. Read scales, charts or meters at the same time every day to determine use of chlorine and any other chemicals. Notify plant superintendent when chlorine supply is low.
4. Look at least once per shift for chlorine and chemical leaks.
5. Try to maintain temperature of storage area below temperature of chlorinator room.
6. Determine manifold pressure before and after chlorine pressure regulating valve.
7. Be sure all chlorine containers are properly secured.

Weekly

1. Clean building or storage area.
2. Check operation of chlorine leak-detector alarm.

Monthly

1. Exercise all valves, including flex connector's auxiliary, manifold, filter bypass, and switchover valves.
2. Inspect all flex connectors and replace any that have been kinked or flattened.
3. Inspect hoisting equipment.
   a. Cables: frayed or cut.
   b. Beams and hooks: cracked or bent.
   c. Controls: operate properly; do not stick or respond sluggishly; cords not frayed; safety chains or cables in place.
4. Examine building ventilation.
   a. Ducts and louvers: clean and operate freely.
   b. Fans and blowers: operate properly; guards in place; equipment properly lubricated.
5. Perform preventive maintenance as scheduled.
   a. Lubricating equipment.
   b. Repacking of valves and regulators.
   c. Cleaning and replacing of valve seats and stems.
   d. Cleaning filters and replacing glass wool. (*CAUTION:* Glass wool soaked with liquid chlorine or chlorine impurities may burn your skin or give off sufficient chlorine gas to be dangerous.)
   e. Painting of equipment.

10.261 Evaporators

Evaporators are used to convert liquid chlorine to gaseous chlorine for use by gas chlorinators.

Daily

1. Check evaporator water bath to be sure water level is at midpoint of sight glass.

2. Be sure water bath temperature is between 160 to 195°F (71 to 91°C). Low alarm should sound at 160°F (71°C) and high alarm should sound at 200°F (93°C).
3. Determine chlorine inlet pressure to evaporator. Pressure should be same pressure as on supply manifold from containers (20 to 100 psi or 1.4 to 7 kg/sq cm).
4. Measure chlorine outlet temperature from evaporator. Typical range is 90 to 105°F (32 to 41°C). High alarm should sound at 110°F (43°C). At low temperatures the chlorine pressure-reducing valve (CPRV) will close due to the low temperature in the water bath.
5. Check CPRV for open-closed position.
6. If evaporator is equipped with water bath recirculation pump at back of evaporator, determine if pump is operating properly.
7. Look for leaks and repair any discovered.

Abnormal Evaporator Conditions

1. Evaporator water level low. Water level not visible in sight glass!

   Troubleshooting Measurements.

   a. Determine actual level of water.

   b. Measure temperature of water.

   c. Check temperature and pressure of chlorine in evaporator system and feed lines back to containers and chlorinators for possible overpressure of system (pressure should not exceed 100 psi or 7 kg/sq cm).

   Corrective Action

   a. If chlorine pressure on system is near or over 100 psi (7 kg/sq cm), close supply-container valves to stop chlorine addition to the system, increase feed rate of chlorinator to use chlorine in the system, and drop the pressure back down to a safe range. *NOTE:* Alarm system is usually set to sound at 110 psi (7.7 kg/sq cm). If system pressure was at or over 110 psi (7.7 kg/sq cm), inspect alarm circuit to determine failure of alarm.

   b. If temperature of water bath is at an abnormal level, find the cause. Water bath levels are usually set in the following sequence:

      1) 160°F or 71°C: low temperature alarm.
      2) 185 to 195°F or 85 to 91°C: normal operating range.
      3) 185°F or 85°C: actuates pressure reducing valve (PRV) to open position.
      4) 200°F or 93°C: high temperature alarm.

      If water temperature is above 200°F (93°C), alarm should have sounded. Open control switch on evaporator heaters to stop current flow to heating elements. If temperature is in normal range, return to correcting the original problem of a low water level.

   c. Evaporator water levels are controlled by a solenoid valve. First check to see if drain valve is fully closed and then use the following steps.

      1) Override solenoid valve and fill water bath to proper level.
      2) If water cannot be added, take evaporator out of service:
         a. Switch to another evaporator, or
         b. Switch supply to gas side of containers.
      3) Repair valve and actuating sensor.

2. Low water temperature in evaporator.

   a. Check chemical (chlorine) flow-through rate. Rate may have exceeded unit's capacity and may require two evaporators to be on line to handle chemical feed rate.

   b. Inspect immersion heaters for proper operation. First examine control panel for thermal overload on breaker. Most evaporators are equipped with two to three heating elements. An inspection of the electrical system will indicate if the breakers are shorted or open and will locate the problem. Replace any heating elements that have failed.

   c. If no spare evaporators are available, operate from the valves on the chlorine gas supply. If necessary, reduce the chlorine feed rate to keep the chlorination system working properly.

3. No chlorine gas flow to the chlorinator.

   a. Inspect pressure-reducing valve downstream from evaporator and determine if valve is in the open or closed position.

      1) Valve may be closed due to low water temperature in evaporator (less than 185°F or 85°C).
      2) Valve may be closed due to loss of vacuum on system or loss of continuity of electrical control circuits which may have been caused by a momentary power drop. Correct problem and reset valve.
      3) Valve may be out of adjustment and restricting gas flow through the valve due to a low pressure setting.

   b. Inspect supply containers and manifold. Possible sources of lack of chlorine gas flow to chlorinators include:

      1) Containers empty.
      2) Container chlorine supply lines incorrectly connected to gas instead of liquid side of containers. High flow rates of gas will freeze chlorine, thus frosting valves and flex connectors.
      3) Chlorine manifold filters plugged. Check pressure upstream and downstream from filter. Pressure drop should not exceed 10 psi (0.7 kg/sq cm). Frost on manifold will indicate a restriction in the filters.
      4) Inspect manifold and system for closed valves. Most systems operate properly with all chlorine valves at only *ONE TURN OPEN* position.

Monthly

1. Exercise all valves, including inlet, outlet, pressure reducing (PRV), water, drain and fill valves.
2. Inspect evaporator cathode-protection meter (if so equipped). Cathodic protection protects the metal water tank (on *SULFONATORS*[30]) and piping from corrosion due to electrolysis. Electrolysis is the flow of electrical current and is the reverse of metal plating. In electrolysis, the flow away of certain compounds from the metal causes corrosion and holes in a short time. This type of corrosion is

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[30] *Sulfonators (see Section 10.8, "Dechlorination") are similar to chlorinators.*

controlled by either a sacrificial anode made of magnesium and zinc or by applied small electrical currents to suppress or reverse the normal corroding current flow.

3. Check setting of PRV (pressure reducing valve) in order to maintain desired pressure of chlorine gas to chlorinators.
4. Inspect heating and ventilation equipment in chlorinator area.
5. Perform scheduled routine preventive maintenance.
   a. Drain and flush water bath.
   b. Clean evaporator tank.
   c. Repack gasket and reseat pressure-reducing valves.
   d. Check heater elements.
   e. Replace anodes.
   f. Paint system.

10.262 Chlorinators Including Injectors

Daily

1. Check injector water-supply pressure. Pressures will range from 40 to 90 psi (2.8 to 6.3 kg/sq cm) depending on system.
2. Determine injector vacuum. Values will range from 15 to 25 inches (38 to 64 cm) of mercury.
3. Check chlorinator vacuum. Values will range from 5 to 10 inches (13 to 25 cm) of mercury.
4. Determine chlorinator chlorine-supply pressure. Values will range from 20 to 40 psi (1.4 to 2.8 kg/sq cm).
5. Read chlorinator feed rate on rotameter tube. Is feed rate at required level? Record rotameter reading and time.
6. Examine and record mode of control.
   a. Manual
   b. Automatic (single input)
   c. Automatic (dual input)
7. Measure chlorine residual at application point.
8. Inspect system for chlorine leaks.
9. Inspect auxiliary components.
   a. Flow signal input. Does chlorinator feed rate change when flow changes? Chlorinator response is normally checked by biasing (adjusting) flow signal which may drive dosage control unit on chlorinator to full open or closed position. When switch is released, chlorinator will return to previous feed rate. During this operation the unit should have responded smoothly through the change. If the response was not smooth, look for mechanical problems of binding, lubrication, or vacuum leaks.
   b. If chlorinator also is controlled by a residual analyzer, be sure the analyzer is working properly. Check the following items.
      1) Actual chlorine residual is properly indicated.
      2) Recorder alarm set point.
      3) Recorder control set point.
      4) Sample water flow.
      5) Sample water flow to cell block after dilution with fresh water.
      6) Adequate flow of dilution water.
      7) Filter system and drain.
      8) Cell block
         a) Buffer pump and solution feed correct. Run pH test of cell block.
         b) Check amount of grit in cell block and add more grit if amount is low. Grit is used to keep the electrode free of slimes and chemical scales in order to provide quick and accurate readings.
         c) Cell block hydraulics purger.
      9) Run comparison tests of chlorine residuals. Do tests match with analyzer output readings?
      10) If residual analyzer samples two streams, start other stream flow and compare tested residual of that stream with analyzer output readings. Standardize analyzer output readings against tested residuals. Enter changes and corrections in log.
      11) Change recorder chart daily.
      12) Check recorder output signal controlling chlorinator for control responses on feed rate. Correct feed rates through ratio controller.

Weekly

1. Put chlorinator on manual control. Operate feed-rate adjustment through full range from zero to full scale (250, 500, 1000, 2000, 4000, 6000, 8000, or 10,000 pounds/day). At each end of scale check:
   a. Chlorinator vacuum.
   b. Injector vacuum.
   c. Solution line pressure.
   d. Chlorine pressure at chlorinator.
   If any of the readings do not produce normal set points, make proper adjustments.
      1) Injector should produce necessary vacuum at chlorinator (5 to 10 inches or 13 to 25 centimeters of mercury).
      2) Adjust PRV to obtain sufficient pressure and chemical feed for full feed-rate operation of chlorinator.
2. If unit performs properly through complete range of feed rates, return unit to automatic control. If any problems develop, locate source and correct.
3. Clean chlorine residual analyzer, including the following items:
   a. Clean filters.
   b. Clean sample line.
   c. Clean hydraulic dilution wells and baffles.
   d. Flush discharge hoses and pipes.
   e. Clean and flush cell block.
   f. Fill buffer reservoirs.
   g. Check buffer pump and feed rate.
   h. Wipe machine clean and keep it clean.

Monthly

1. Exercise all chlorine valves.
2. Inspect heaters and room ventilation equipment.
3. Check chlorinator vent line to outside of structure for any obstructions that could prevent free access to the atmosphere. Bugs and wasps like vent lines for nests.

4. Inspect unit for vacuum leaks.
5. Clean rotameter sight glass.
6. Inspect all drain lines and hoses.
7. Perform scheduled routine maintenance.
   a. Disassemble, clean and regasket chlorinator (once a year).
   b. Repack seat and stem of valves.
   c. Inspect tubing and fittings for leaks. Wash and dry thoroughly before reassembling.
   d. Inspect control system.
      1) Electrical and electronics
      2) Pneumatics
      3) Lubrication
      4) Calibration of total system
   e. Chlorine analyzer.
      1) Lubrication of chart drives, filter drives and pumps.
      2) Clean and flush all piping and hoses, filters, tubing, cell blocks and hydraulic chambers.
      3) Replace electrodes in cell block.
      4) Replace buffer pumps and system solenoids. Clean acid and iodide reservoirs.
      5) Calibrate unit with known standards.
      6) Repaint unit.
   f. Inspect safety equipment, including self-contained breathing equipment and repair kits.

Possible Abnormal Conditions

1. Chlorine leak in chlorinator.
   Shut off gas flow to chlorinator. Leave injector on line. Allow chlorinator to operate and empty chlorine gas for three to five minutes with zero psi showing on the chlorine pressure gage. Repair leak or switch to another chlorinator and repair leak.
2. Gas pressure too low, less than 20 psi (1.4 kg/sq cm). Alarm indicated. Check chlorine supply:
   a. Empty containers, switch to standby units.
   b. Evaporator shut down. See section 10.261, "Evaporators."
   c. Inspect manifold for closed valves or restricted filters. Correct by switching to another manifold or setting valves and controls to proper position.
3. Injector vacuum too low.
   a. Adjust injector to achieve required vacuum.
   b. Inspect injector water supply system.
      1) Pump off: start pump.
      2) Strainers dirty: clean strainers.
      3) Pump worn out and will not deliver appropriate flow and pressure to injector: use other unit and/or repair or replace pump.
   c. Inspect solution line discharge downstream from injector. Check for the following items:
      1) Valve closed or partially closed.
      2) Line broken or restriction reducing flow or increasing back pressure.
      3) Diffuser plugged, thus restricting flow and creating a higher back pressure on discharge line and injector. Clean diffuser and flush pipe.
4. Low Chlorine Residual. Alarm indicator is on from chlorine residual analyzer.

   Determine actual chlorine residual and compare with residual reading from chlorine analyzer. If residual analyzer is off, recalibrate analyzer and readjust. If chlorine residual analyzer is correct and chlorine residual is low, check the following items:
   a. Sample pump
      1) Operation, flow and pressure.
      2) Sample lines clean and free of solids or algae that could create a chlorine demand.
      3) Strainer dirty and restricting flow, thus preventing adequate pressure (15 to 20 psi or 1.0 to 1.4 kg/sq cm) at analyzer.
   b. Control system if chlorinator is on automatic control. If chlorine feed rate remains too low, take chlorinator off of automatic control and switch to manual control. Set chlorinator to proper feed rate as determined by previous adequate feed rates (see Section 10.28, "Operational Strategy").
   c. Chlorine demand higher than the amount one chlorinator can supply. Place additional chlorinator on line.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.2L Normal operation of a chlorinator includes daily inspection of what facilities or areas?

10.2M What is the purpose of evaporators?

10.2N What abnormal conditions could be encountered when operating an evaporator?

10.2O How can you determine if chlorine residual analyzer is working properly?

10.2P What are possible chlorinator abnormal conditions?

10.27 Shutdown of a Chlorinator

10.270 Short-Term Shutdown

The following is a typical procedure for shutting down a chlorinator for a time period of less than one week.

1. Close chlorine-container gas outlet valve.
2. Allow chlorine gas to completely evacuate the system through the injector. Chlorine gas pressure gages will fall to zero psi on the manifold and the chlorinator.
3. Close chlorinator gas discharge valve. The chlorinator may remain in this condition indefinitely and is ready to be placed back in service by reopening the chlorinator discharge valve and chlorine-container gas outlet valve. After these valves have been reopened, inspect for chlorine leaks throughout the chlorination system.

10.271 Long-Term Shutdown

1. Perform steps one, two and three above for short-term shutdown.
2. Turn off chlorinator power switch, lock out and tag.
3. Secure chlorinator gas manifold and chlorinator valve in closed position.

10.28 Operational Strategy

The operator should strive to keep the chlorination system well maintained and operational. There will be occasions when pieces of equipment will be out of service for maintenance and repair. These activities should be scheduled during the times of the year when demands on the chlorination system are low. Plants may be required to provide chlorination services for:

1. Disinfection:	postchlorination of effluent.
2. Process Control:	activated sludge and trickling filter treatment processes.
3. Odor Control:	usually seasonal during the warmer months from May through October.
4. Dechlorination:	usually seasonal during July through November (see Section 10.8, "Dechlorination." Chlorination and dechlorination facilities are similar).

Under these circumstances, maintenance of chlorination facilities requiring tearing down, cleaning, repairing and reassembling should be done during the winter months of November through April. If a chlorination unit fails, there will be standby capabilities for at least post-chlorination to disinfect the plant effluent. Even if all systems fail, the operator is still expected to meet discharge disinfection requirements. A supply of HTH or other dry hypochlorite compound should be available for emergencies of this nature because dry hypochlorite compounds can be fed manually while repairs are being made. A table of dosages or calculation procedures and a calibrated measuring container should be available so the proper dosage of chemical can be applied.

Usually wastewater treatment plants are designed and equipped with standby or backup capabilities so at least the effluent can be disinfected. In this case, two areas could cause trouble:

1. Run out of chlorine.

   This problem is strictly the operator's problem. You are the only person who maintains the chlorine supply inventory. You must request more chlorine with sufficient lead time for the vendor to acquire and deliver the chlorine. Therefore, your plant should never run out of chlorine or any other chemical.

   Care must also be exercised that the connected containers do not empty and that sufficient containers are connected so that the maximum dosage rates can be achieved without exceeding maximum withdrawal rates from the connected containers. Weighing scales or automatic switchover equipment should always be provided. The latter is highly desirable particularly when the plant is unattended part of the day. Even in this case, it is important to note when the switchover has occurred so that the empty containers can be replaced with full ones before the second set empties.

2. Failure of automatic control equipment.

   Assume you are operating a chlorination system on "auto" control to meet NPDES-permit coliform requirements. A 4.5 mg/*L* chlorine residual must be maintained at the outlet of the chlorine contact basin to meet this requirement at your plant. If the plant operators have recorded the past chlorinator feed rates every two hours during daily routine checks, a history of feed rates at various times during the day will have been established for "auto" control. With this information available, manual operation only requires setting the feed rate to correspond to the same hour and flow conditions. Daily flows at most treatment plants are consistent (except during storm flows) where feed rates are known for every day of the year. By reviewing dates for the same day for three previous weeks, the information below can be obtained and calculations can be made for intermediate hours (1000 and 1200 hours). To calculate these suggested manual feed rates, determine the average feed rate between the 0900 and 1100 average feed rates and also between the 1100 and 1300 average feed rates. See Volume II, Section 18.4, "Average or Arithmetic Mean," page 508, and Section A.35, "Data Analysis," page 577.

Time	Last Week	Two Weeks Ago	Three Weeks Ago	Average	Suggested Manual Feed Rates
0900	1055 lb/day	1065 lb/day	1060 lb/day	1060 lb/day	1060 lb/day
1000	—	—	—	—	1500 lb/day
1100	1900 lb/day	1900 lb/day	1800 lb/day	1900 lb/day	1900 lb/day
1200	—	—	—	—	1900 lb/day
1300	1800 lb/day	1850 lb/day	1850 lb/day	1850 lb/day	1850 lb/day

By recording readings of chlorine feed rates, it is very simple to manually program equipment and maintain high plant performance during instrumentation or equipment failures. In this example, note that the suggested feed rate is adjusted manually every hour in an attempt to provide adequate disinfection at all times.

10.29 Chlorine Troubleshooting Guide

CHLORINE CONTACT CHAMBER

Operating Symptoms	Probable Cause	Remedy
Increase in coliform level	Low residual	Increase chlorine dose.
	Organic strength increase in effluent	Improve biological treatment process including secondary clarification and/or increase chlorine dose.
	Mixing problems	Baffle the chamber. Install mixer.
	Short-circuiting	Install baffles.
	Solids accumulation in chamber	Take chamber out of service and clean.
	Large variation in flow (surges)	Change to steady flow.
	Diffuser plugged	Clean diffuser.
Drop in chlorine residual	Organic strength increase	Increase dosage. Inspect rest of plant for possible problems. Check dischargers into the system, especially industrial discharges.
	Solids accumulation in chamber	Take chamber out of service and clean.
	Flow change	Adjust dosage for flow.
	Equipment failure	Repair.
Increase in chlorine residual	Organic strength decrease	Lower dosage.
	Flow change	Correct dosage.
BREAKOUT OF CHLORINE[31]	Overfeeding chlorine	Decrease chlorine feed rate.
	Insufficient flow in injector water supply	Increase flow in injector water supply
	Mixing	Turn off mixer because mixing can encourage release of chlorine gas under breakout conditions. If chlorine gas continues to be released, corrosion damage can occur to mixer and structure.
	Diffuser	Lower diffuser. or Install a larger diffuser to cover a bigger area.

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[31] *Breakout of Chlorine. A point at which chlorine leaves solution as a gas because chlorine feed rate is too high. The solution is saturated and cannot dissolve any more chlorine.*

CHLORINATOR AND EVAPORATOR

Operating Symptoms	**Probable Cause**	**Remedy**
Loss of chlorine pressure at the chlorinator	Plugged chlorine gas filter on gas phase	Clean filter.
	Out of chlorine	Switch to another container.
	Supply valve closed or partly closed	Open valve.
Liquid through manometer	Defective evaporator	Repair evaporator.
	Dosage too high	Lower dosage. Use another chlorinator.
Loss of vacuum	Plugged diffuser	Repair diffuser.
	Injector problems	Repair injector.
	Loss of water pressure	Check water supply.
	Vacuum leak in chlorinator	Locate and stop leak. Usually leak is caused by unseated rotameter tube, leaky gasket or ruptured diaphragm.
High vacuum	Loss of chlorine supply	Check supply system.
Misting	Defective evaporator	Repair evaporator.
	Evaporator undersized	Operate two evaporators or reduce chlorine feed rate.
Low temperature alarm on evaporator	Water bath	Clean water bath.
	Power loss	Check electrical system.
	Heater element burned out	Repair by replacing heater element.
Chlorinator will not come up to full feed. Gas pressure adequate	Injector vacuum does not develop	Repair injector. Clean piping.
Chlorinator feeds OK at high rates but will not control feed at low rates.	Chlorinator pressure reducing valve (CPRV) not working properly	Clean CPRV. Check for leaks in CPRV diaphragm.
	Possibly a bad diaphragm in vacuum	Replace diaphragm.
	Reducing valve is causing bypassing of V-notch control valve	Replace valve.
Chlorinator controls OK at low feeds but are erratic when full feed is attempted. Injector vacuum is OK	Not enough chlorine for demand	Clean CPRV cartridge.
	Dirty CPRV or partially clogged gas line	Clean high-pressure gas line.
		Supply adequate chlorine gas pressure.
Chlorinator does not feed. Gas pressure is adequate. Injector vacuum OK	Tube connection from upstream of V notch to top of differential valve is disconnected or leaking	Reconnect tube line.
		Replace tube if cracked, kinked or defective at ends.
		Tighten tube nuts.
A variable vacuum-control chlorinator formerly working normally, now won't go below about 30% feed. Signal levels OK	CPRV not throttling sufficiently for low feeds	Clean CPRV cartridge.
		Readjust CPRV bias.
A variable vacuum-control chlorinator reaches full feed, but won't go below about 45 to 50% feed. CPRV is OK	Signal vacuum is too high because of air leak through diaphragm or control vacuum check valve is bypassing restrictor	Replace diaphragm, gasket or stem as tests indicate source of leak.
		Clean and dry or replace filter disc.
		Clean converter nozzle.

CHLORINE SUPPLY SYSTEM

Operating Symptoms	Probable Cause	Remedy
Discoloration at joint. Green scum on cadmium plating gone and replaced by reddish color	Leaks	Repair by replacing.
Small droplet of liquid on joint	Leaks	Repair as quickly as possible.
Leaks at gas gages or pressure switches	Leaks	Repair gage or pressure switch.
Gooey, taffy-like mass	Moisture in supply	Clean filters. Taffy caused in manufacturing process.
High-pressure alarm	Defective silver diaphragm on gage or pressure switch	Repair diaphragm or switch.
Cold or freezing areas on the supply system	Restriction in line	Repair.
	Withdrawal rate too rapid	Lower withdrawal rate. Place more chlorine containers on line.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.2Q List the steps for a short-term shutdown of a chlorinator.

10.2R What are two areas that could hinder your ability to meet NPDES-permit coliform requirements when your plant is equipped with standby or backup capabilities?

Please answer the discussion and review questions before continuing with Lesson 3.

END OF LESSON 2
OF 5 LESSONS ON
DISINFECTION
AND
CHLORINATION

DISCUSSION AND REVIEW QUESTIONS

Chapter 10. DISINFECTION AND CHLORINATION

(Lesson 2 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 1.

7. Where might chlorine be applied in the treatment of wastewater?
8. Where is chlorine usually applied for disinfection purposes?
9. What is the ultimate control of chlorine dosage for disinfection?
10. Determine the chlorine feed rate for a flow of 0.75 MGD and a chlorine dosage of 18 mg/*L*?
11. Why must the chlorine solution be well mixed with the wastewater?
12. What precautions would you take before starting any chlorination system?
13. When should the maintenance and repair of chlorination systems be scheduled?

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 3 of 5 Lessons)

10.3 CHLORINE SAFETY PROGRAM

Every good safety program begins with cooperation between the employee and the employer. The employee must take an active part in the overall program. The employee must be responsible and should take all necessary steps to prevent accidents. This begins with the attitude that as good an effort as possible must be made by everyone. Safety is everyone's problem. The employer also must take an active part by supporting safety programs. There must be funding to purchase equipment and to enforce safety regulations required by OSHA and industrial safety programs. The following items should be included in all safety programs.

1. Establishment of a safety program.
2. Written rules.
3. Periodic hands-on training using safety equipment:
    a) Leaks-detection equipment
    b) Gas masks
    c) Atmospheric monitoring devices
4. Establishment of emergency procedures for chlorine leaks and first aid.
5. Establishment of a maintenance and calibration program for safety devices and equipment.

All persons handling chlorine should be thoroughly aware of its hazardous properties. Personnel should know the location and use of the various pieces of protective equipment and be instructed in safety procedures. In addition, an emergency procedure should be established and each individual should be instructed how to follow the procedures. An emergency checklist also should be developed and available. For additional information on this topic, see the Water Pollution Control Federation's Manual of Practice No. 1, *SAFETY AND HEALTH IN WASTEWATER SYSTEMS*, and the Chlorine Institute's *CHLORINE MANUAL*, 4th edition.[32] Also see Chapter 14, "Plant Safety and Good Housekeeping."

10.30 Chlorine Hazards

Chlorine is a gas, heavier than air, extremely toxic and corrosive in moist atmospheres. Dry chlorine gas can be safely handled in steel containers and piping, but with moisture must be handled in corrosion-resisting materials such as silver, glass, teflon, and certain other plastics. Chlorine gas at container pressure should never be piped in silver, glass, teflon, or any other plastic material. Even in dry atmospheres, the gas is very irritating to the mucous membranes of the nose, to the throat, and to the lungs; a very small percentage in the air causes severe coughing. Heavy exposure can be fatal. (See Table 10.1).

WARNING

WHEN ENTERING A ROOM THAT MAY CONTAIN CHLORINE GAS, OPEN THE DOOR SLIGHTLY AND CHECK FOR THE SMELL OF CHLORINE. **NEVER** GO INTO A ROOM CONTAINING CHLORINE GAS WITH HARMFUL CONCENTRATIONS IN THE AIR WITHOUT A SELF-CONTAINED AIR SUPPLY, PROTECTIVE CLOTHING AND HELP STANDING BY. HELP MAY BE OBTAINED FROM YOUR CHLORINE SUPPLIER AND YOUR LOCAL FIRE DEPARTMENT.

10.31 Why Chlorine Must Be Handled With Care

You must always remember that chlorine is a hazardous chemical and must be handled with respect. Concentrations of chlorine gas in excess of 1000 ppm may be fatal after a few breaths.

TABLE 10.1 PHYSIOLOGICAL RESPONSE TO CONCENTRATIONS OF CHLORINE GAS[33]

Effect	Parts of Chlorine Gas Per Million Parts of Air By Volume (ppm)
Slight symptoms after several hours' exposure	1
Detectable odor	3
60-minute inhalation without serious effects	4
Noxiousness	5
Throat irritation	15
Coughing	30
Dangerous from one-half to one hour	40
Death after a few deep breaths	1000

Because the characteristic sharp odor of chlorine is noticeable even when the amount in the air is small, it is usually possible to get out of the gas area before serious harm is suffered. This feature makes chlorine less hazardous than gases such as carbon monoxide, which is odorless, and hydrogen sulfide, which impairs your sense of smell in a short time.

Inhaling chlorine causes general restlessness, panic, severe irritation of the throat, sneezing, and production of much saliva. These symptoms are followed by coughing, retching and vomiting, and difficulty in breathing. Chlorine is particularly irritating to persons suffering from asthma and certain types of chronic bronchitis. Liquid chlorine causes severe irritation and blistering on contact with the skin.

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[32] *Write to: Water Pollution Control Federation, Publications Order Department, 601 Wythe Street, Alexandria, VA 22314-1994. Order #M0001DT, price to WPCF members, $26.00; others, $35.00 plus $4.75 postage. The Chlorine Institute, Inc., 2001 L Street, Suite 506, Washington, DC 20036; price $10.00.*

[33] *Adapted from data in U.S. Bureau of Mines* TECHNICAL PAPER 248 *(1955).*

10.32 Protect Yourself From Chlorine

Every person working with chlorine should know the proper ways to handle it, should be trained in the use of self-contained breathing apparatus, and should know what to do in case of emergencies.

> **WARNING**
>
> CANISTER-TYPE 'GAS MASKS' ARE USUALLY **INADEQUATE** AND **INEFFECTIVE** IN SITUATIONS WHERE CHLORINE LEAKS OCCUR AND ARE THEREFORE NOT RECOMMENDED FOR USE UNDER ANY CIRCUMSTANCES. **SELF-CONTAINED AIR OR OXYGEN SUPPLY-TYPE BREATHING APPARATUS ARE RECOMMENDED.**

Self-contained air supply and demand-breathing equipment must fit properly and be used properly. Pressure demand and rebreather kits may be safer. Pressure demand units use more air from the air bottle which reduces the time a person may work on a leak.

Before entering an area with a chlorine leak, wear protective clothing. Gloves and a rubber suit will prevent chlorine from contacting the sweat on your body and forming hydrochloric acid. Rubber suits are very cumbersome, but should be worn when the weather is hot and humid and the chlorine concentration is high. Otherwise, use your own judgment regarding whether or not to wear protective clothing.

The best protection that one can have when dealing with chlorine is to respect it. Each individual should practice rules of safe handling and good *PREVENTIVE MAINTENANCE.*

Prevention is the best emergency tool you have.

Plan ahead.

1. Have your fire department tour the area so that they know where the facilities are located. Give them a clearly marked map indicating the location of the chlorine storage area, chlorinators, and gas masks.
2. Have emergency drills using chlorine gas masks and chlorine repair kits.
3. Have a supply of ammonia available to detect chlorine leaks.
4. Write emergency procedures:

   Prepare a *CHLORINE EMERGENCY LIST* of names or companies and phone numbers of persons to call during an emergency. This list should include:

   a. Fire department,
   b. Chlorine emergency personnel, and
   c. Chlorine supplier.
5. Follow established procedures during all emergencies.
   a. Never work alone during chlorine emergencies.
   b. Obtain help immediately and quickly repair the problem. *PROBLEMS DO NOT GET BETTER.*
   c. Only authorized and properly trained persons with adequate equipment should be allowed in the danger area to correct the problem.
   d. If you are caught in a chlorine atmosphere without a gas mask, shallow breathing is safer than breathing deeply. Recovery depends upon the duration and amount of chlorine inhaled, so it is important to keep that amount as small as possible.
   e. If you discover a chlorine leak, leave the area immediately unless it is a very minor leak. Small leaks can be found by using a rag soaked with ammonia. A white gas will form near the leak so it can be located and corrected.
   f. Notify your police department that you need help if it becomes necessary to stop traffic on roads and to evacuate persons in the vicinity of the chlorine leak.
6. Develop emergency evacuation procedures for use during a serious chlorine leak. Coordinate these procedures with your police department and other officials.
7. Post emergency procedures in all operating areas.
8. Inspect equipment and routinely make any necessary repairs.
9. At least twice weekly, inspect area where chlorine is stored and where chlorinators are located. Remove all obstructions from the area.
10. Schedule routine maintenance on *ALL* chlorine equipment at least once every six months or more frequently.
11. Have health appraisal for employees on chlorine emergency duty. All those who have heart and respiratory problems should not be allowed on emergency teams.

Remember:

Small amounts of chlorine cause large problems. Leaks never get better.

10.33 First Aid Measures

Mild Cases

Whenever you have a mild case of chlorine exposure which does happen from time to time around chlorination equipment, you should first leave the contaminated area. Move slowly, breathe lightly without exertion, remain calm, keep warm and resist coughing. Notify other operators and have them repair the leak immediately.

If clothing has been contaminated, remove as soon as possible. Otherwise the clothing will continue to give off chlorine gas which will irritate the body even after leaving the contaminated area. Immediately wash off area affected by chlorine. Shower and put on clean clothes.

If victim has slight throat irritation, immediate relief can be accomplished by drinking milk. Drinking spirits of peppermint also will help reduce throat irritation.

Extreme Cases

1. Follow established emergency procedures.
2. Always use proper safety equipment. Do not enter area without gas masks with a self-contained breathing apparatus.
3. Remove patient from affected area immediately.
4. First aid:
    a. Remove contaminated clothes to prevent clothing giving off chlorine gas which will irritate the body.
    b. Keep patient warm and cover with blankets if necessary.
    c. Place patient in a comfortable position on back.
    d. *EYES!*
    If even a small amount of chlorine gets into the eyes, they should be flushed with water. The flushing should continue so that all traces of chlorine are flushed from the eyes.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.3A What are the hazards of chlorine gas?

10.3B What type of breathing apparatus is recommended when repairing a chlorine leak?

10.3C What first aid measures should be taken if a person comes in contact with chlorine?

10.4 CHLORINE HANDLING

10.40 Chlorine Containers

10.400 Cylinders

Cylinders containing 100- to 150-pounds (45- to 68-kg) of chlorine are convenient for very small treatment plants with capacities less than 0.5 MGD (1890 cu m/day). These cylinders are usually of seamless steel construction (Fig. 10.7).

A fusible plug is placed in the valve below the valve seat (Fig. 10.8). This plug is a safety device. The fusible metal softens or melts at 158° to 165°F (70° to 74°C) to prevent buildup of excessive pressures and the possibility of rupture due to a fire or high surrounding temperatures.

Cylinders will not explode and can be handled safely.

The following are procedures for handling chlorine cylinders.

1. Move cylinders with a properly balanced hand truck with clamp supports that fasten at least two-thirds of the way up the cylinder.
2. 100- and 150-pound (45- to 68-kg) cylinders can be rolled in a vertical position. Lifting of these cylinders should be avoided except with approved equipment. Never lift with chains, rope slings, or magnetic hoists.
3. Protective cap should always be replaced when moving a cylinder.
4. Cylinders should be kept away from direct heat (steam pipes or radiators).
5. Cylinders should be stored in an upright position.
6. Cylinders must be firmly secured to an immovable object.

10.401 Ton Tanks

Ton tanks are of welded construction and have a loaded weight of as much as 3700 pounds (1680 kg). They are about 80 inches (200 cm) in length and 30 inches (75 cm) in outside diameter. The ends of the tanks are crimped inward to provide a substantial grip for lifting clamps (Fig. 10.9).

The following are some characteristics of and procedures for handling ton tanks.

Most ton tanks have eight openings for fusible plugs and valves (Figs. 10.9 and 10.10). Generally, two operating valves are located on one end near the center. There are six or eight fusible metal safety plugs, three or four on each end. These are designed to melt within the same temperature range as the safety plug in the cylinder valve.

WARNING

IT IS **VERY IMPORTANT** THAT FUSIBLE PLUGS SHOULD NOT BE TAMPERED WITH **UNDER ANY CIRCUMSTANCES** AND THAT THE TANK SHOULD NOT BE HEATED. ONCE THIS PLUG OPENS, ALL OF THE CHLORINE IN THE TANK WILL BE RELEASED.

Ton tanks are shipped by rail in multi-unit tank cars. They also may be transported by truck or semi-trailer.

Ton tanks should be handled with a suitable lift clamp in conjunction with a hoist or crane of at least two-ton capacity (Fig. 10.9).

Ton tanks should be stored and used on their sides, above the floor or ground, on steel or concrete supports. They should not be stacked more than one high.

Ton tanks should be placed on trunnions (pivoting mounts) which are equipped with rollers so that the withdrawal valves may be positioned one above the other. The upper valve will discharge chlorine gas, and the lower valve will discharge liquid chlorine (see Fig. 10.9). Trunnion rollers should not exceed 3-1/2 inches (9 cm) in diameter so that the containers will not rotate too easily and be turned out of position. Roller shafts should be equipped with a zerk-type lubrication fitting. Roller bearings are not advised because of the ease with which they rotate. Locking devices should be used when these rules are observed to prevent ton tanks from rolling while connected.

10.402 Chlorine Tank Cars

Chlorine tank cars are of 16-, 30-, 55-, 85-, or 90-ton capacity. All have four-inch (10 cm) cork board insulation protected by a steel jacket. The dome of the standard car contains four angle valves plus a safety valve. The two angle valves located on the axis line of the tank are equipped for discharging liquid chlorine. The two angle valves at right angles to the axis of the tank deliver gaseous chlorine (Fig. 10.11).

Unloading of tank cars should be performed by trained personnel in accordance with Interstate Commerce Commission (ICC) regulations.

In most situations, chlorine is withdrawn from tank cars as a liquid and then passed through chlorine evaporators. Sometimes *DRY* air is passed into the tank car through one of the gas valves to assist in liquid withdrawal. This practice is referred to as *AIR PADDING*.[34]

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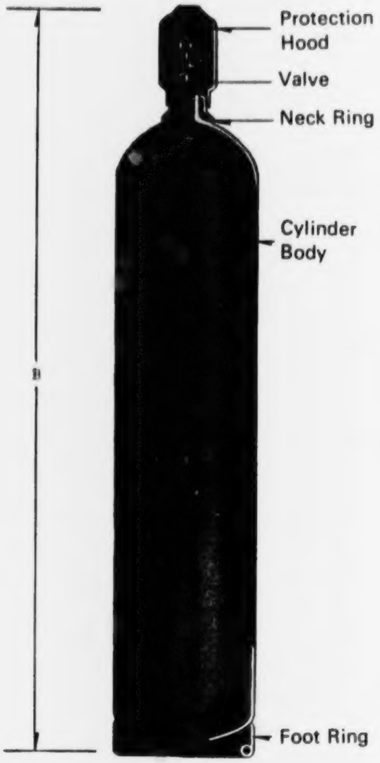
[34] ***Air Padding.*** *Pumping dry air into a container to assist with the withdrawal of a liquid or to force a liquid gas such as chlorine or sulfur dioxide out of a container.*

Chlorine Cylinder


Protection Hood
Valve
Neck Ring
Cylinder Body
Foot Ring
B

Net Cylinder Contents	Approx. Tare, Lbs.*	Dimensions, Inches	
		A	B
100 Lbs.	73	8¼	54½
150 Lbs.	92	10¼	54½

*Stamped tare weight on cylinder shoulder does not include valve protection hood.

Fig. 10.7 Chlorine cylinder
(Courtesy of PPG Industries, Inc., Chemical Division)

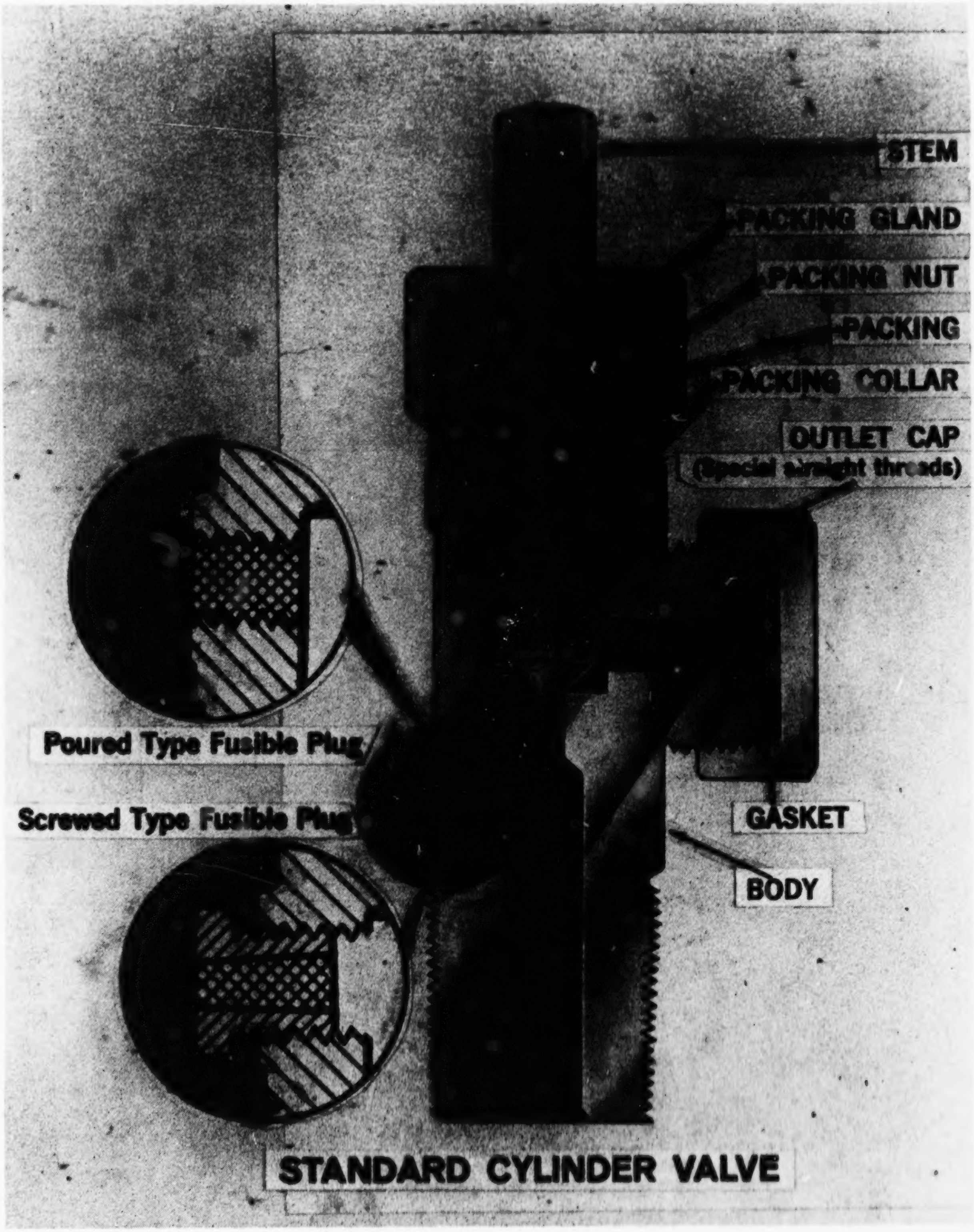
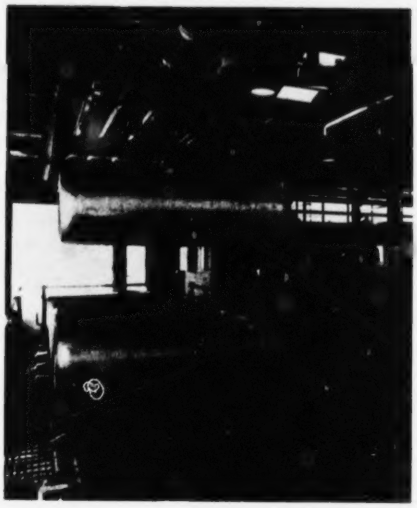

STEM
PACKING GLAND
PACKING NUT
PACKING
PACKING COLLAR
OUTLET CAP
(Special straight threads)
Poured Type Fusible Plug
Screwed Type Fusible Plug
GASKET
BODY
STANDARD CYLINDER VALVE

Fig. 10.8 Standard cylinder valve
(Reproduced with permission of the Dow Chemical Company (1959, 1966))



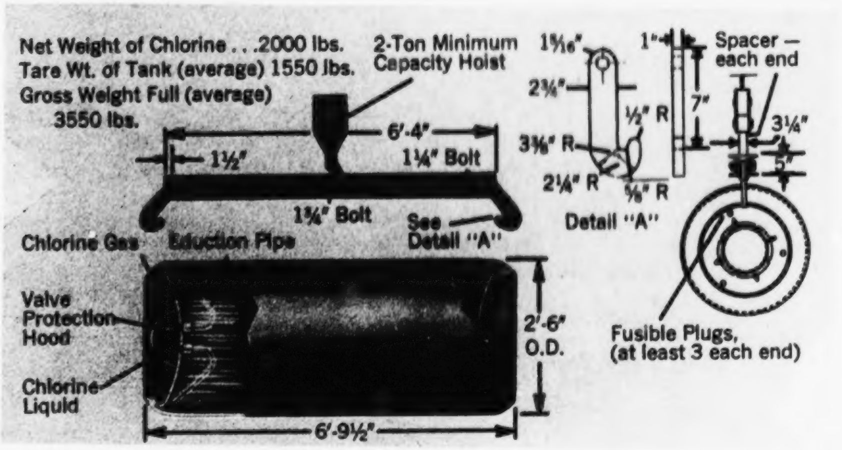

Net Weight of Chlorine . . .2000 lbs.
Tare Wt. of Tank (average) 1550 lbs.
Gross Weight Full (average)
3550 lbs.
2-Ton Minimum Capacity Hoist
6'-4"
1½"
1¼" Bolt
1¾" Bolt
See Detail "A"
Chlorine Gas
Eduction Pipe
Valve Protection Hood
Chlorine Liquid
2'-6" O.D.
6'-9½"
1⁹⁄₁₆"
2¾"
½" R
3⅜" R
2¼" R
⅝" R
Detail "A"
1"
7"
Spacer — each end
3¼"
5"
Fusible Plugs, (at least 3 each end)

Fig. 10.9 Ton tank lifting beam
(Courtesy of PPG Industries, Inc., Chemical Division)

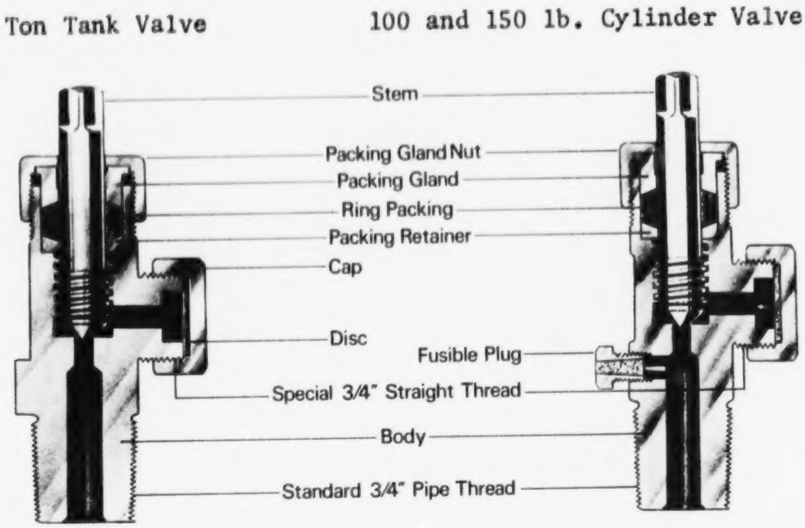

Ton Tank Valve
100 and 150 lb. Cylinder Valve
Stem
Packing Gland Nut
Packing Gland
Ring Packing
Packing Retainer
Cap
Disc
Fusible Plug
Special 3/4" Straight Thread
Body
Standard 3/4" Pipe Thread

Fig. 10.10 Comparison of ton tank valve with cylinder valve

(Courtesy of PPG Industries, Inc., Chemical Division)

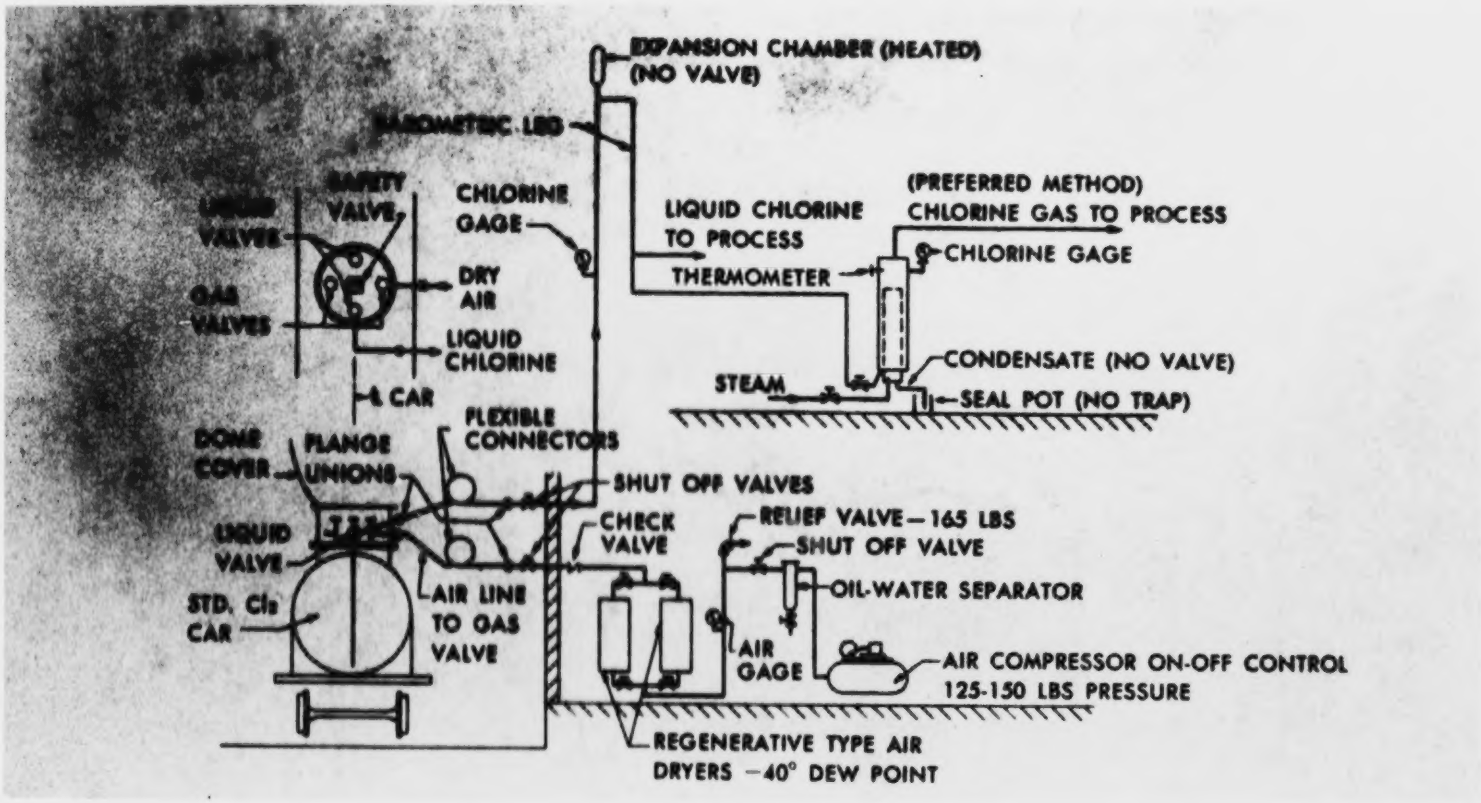

EXPANSION CHAMBER (HEATED)
(NO VALVE)
BAROMETRIC LEG
SAFETY VALVE
LIQUID VALVES
GAS VALVES
CHLORINE GAGE
DRY AIR
LIQUID CHLORINE
℄ CAR
LIQUID CHLORINE TO PROCESS
(PREFERRED METHOD)
CHLORINE GAS TO PROCESS
CHLORINE GAGE
THERMOMETER
CONDENSATE (NO VALVE)
STEAM
SEAL POT (NO TRAP)
DOME COVER
FLANGE UNIONS
FLEXIBLE CONNECTORS
SHUT OFF VALVES
CHECK VALVE
RELIEF VALVE—165 LBS
SHUT OFF VALVE
LIQUID VALVE
OIL-WATER SEPARATOR
STD. Cl₂ CAR
AIR LINE TO GAS VALVE
AIR GAGE
AIR COMPRESSOR ON-OFF CONTROL
125-150 LBS PRESSURE
REGENERATIVE TYPE AIR DRYERS −40° DEW POINT

Fig. 10.11 Typical chlorine tank car unloading arrangement

(Reproduced with permission of The Dow Chemical Company (1959, 1966))

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.4A How may chlorine be delivered to a plant?

10.4B What is the purpose of the fusible plug?

10.41 Removing Chlorine From Containers

10.410 Connections

Outlet threads on container valves are not tapered pipe threads. Use fittings and gaskets for connections furnished by your chlorine supplier or chlorinator equipment manufacturer. Do not try to use regular pipe thread fittings. Whenever a new connection is made, a new gasket should be used.

Flexible 3/8-inch 2000-pound (psi) (0.95 cm, 140 kg/sq cm) annealed (toughened) copper tubing is recommended for connections between chlorine containers and stationary piping. Care should be taken to prevent sharp bends in the tubing because this will weaken it and eventually the tubing will start leaking. Many operators recommend use of a sling to hold the tubing when disconnecting it from an empty cylinder to prevent the tubing from flopping around and getting kinked or getting dirt inside it.

A shutoff valve is needed after the container valve or at beginning of stationary piping to simplify changing of containers.

Whenever changing a chlorine container, use new washers or gaskets. Always purchase washers or gaskets from your chlorine supplier in order to obtain the proper material.

10.411 Valves

Do not use wrenches longer than six inches (15 cm), pipe wrenches, or wrenches with an extension on container valves. To unseat, strike end of wrench with heel of hand to rotate the valve stem in a counterclockwise direction. Then open slowly.

One complete turn permits maximum discharge. Do not force valve beyond this point.

If valve is too tight to open, loosen the packing gland nut (Fig. 10.10) slightly to free the stem.

10.412 Ton Tanks

One-ton tanks (Fig. 10.9) must be *PLACED ON THEIR SIDES WITH THE VALVES IN A VERTICAL POSITION*. Connect the flexible tubing to the *TOP VALVE* to remove chlorine gas from a tank. The *BOTTOM VALVE* is used to remove liquid chlorine and is used only with a chlorine evaporator. The valves are similar to those on the smaller chlorine cylinders (fusible plugs are not located at valves on ton containers) and must be handled with the same care.

10.413 Railroad Tank Cars

Unloading of tank cars must be performed by trained personnel in accordance with Interstate Commerce Commission (ICC) regulations. Figure 10.12 shows tne layout of a facility for unloading a railroad tank car. This section lists the procedures to follow to safely receive, connect and disconnect railroad tank cars. Your facility may be slightly different. This procedure can be made more specific for your facility by numbering each valve in the procedures.

Receiving Tank Cars

1. Inspect and refuse delivery if car is damaged or has corrosion that would make it unsafe. Once the tank car has been uncoupled, the railroad is relieved of all responsibility. Check that the invoice numbers match with the numbers on the car.
2. Spot the tank car so the draw bridge matches up or lines up with the car carwalk.
3. Verify that the railroad has set the brakes.
4. Set two wheel chocks, one before and one after, on the rail nearest the chlorine tower.
5. Place warning light and sign one car length from tank car.
6. Close and lock derailing mechanism.
7. Record on log sheet the date and time the tank car arrived and was accepted or rejected on treatment plant property.
8. Sign name on log sheet.

Connecting Tank Cars

1. Material needed before leaving office.
    - a. Keys to tool locker on chlorine tower.
    - b. Electrical safety tag.
    - c. A buddy; no one is to work alone on the chlorine tower.
2. Verify that valves are closed.
3. Tag pad air compressor so it will not be turned off during purging operations.
4. Check eyewash and shower for operation.
5. Put on escape respirator.
6. Lower and lock down draw bridge.
7. Check that initial valves are closed.
8. Open pad air valve if pad is higher than chlorine.
9. Open tank car lid and verify that all car valves are closed.
10. Remove plug from tank car valve farthest from the chlorine tower and install gage assembly.
11. Record pressure.
12. Install flex air hose.
13. Open valves to initiate purging of chlorine flex line. Valves should be opened only slightly until the chlorine flex line is completely connected.
14. Remove plug from tank car valve and connect chlorine flex line. *USE A NEW LEAD WASHER IN THE AMMONIA COUPLING*.
15. After no leaks can be heard from connections, close valves.
16. Remove flex air hose.
17. Open valve on tank car. *TEST WITH AMMONIA GAS*.

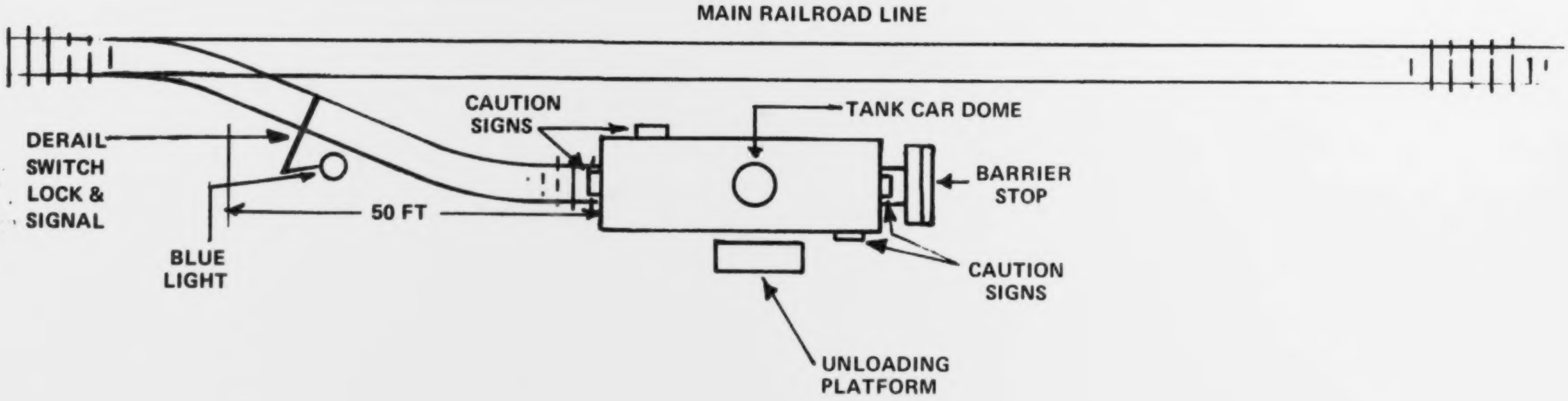

MAIN RAILROAD LINE
CAUTION SIGNS
TANK CAR DOME
DERAIL
SWITCH LOCK & SIGNAL
BARRIER STOP
50 FT
BLUE LIGHT
CAUTION SIGNS
UNLOADING PLATFORM

Fig. 10.12 Layout for unloading railroad tank car

18. Open valves. *TEST WITH AMMONIA GAS*.
19. Record downstream pressure.
20. Open valves. This will connect chlorine tower to chlorine building.
21. Store all gear and lock tool cabinet.
22. Remove compressor tag.
23. Change sign on valves.
24. Record date and time job was completed on log sheet.
25. Sign name on log sheet.
26. Record date and time tank car was placed in service.
27. Record date and time tank car was taken out of service.

Disconnecting Tank Cars

1. Materials needed before leaving office.
   a. Keys to tool locker on chlorine tower.
   b. Electrical safety tag.
   c. A buddy; no one is to work alone on the chlorine tower.
2. Verify valves are closed.
3. Tag pad air compressor so it will not be turned off during purging operations.
4. Check eyewash and shower for operation.
5. Put on escape respirator.
6. Close valve that disconnects the chlorine tower from the chlorine building.
7. Verify that pad air pressure is higher than liquid chlorine line.
8. Open pad air supply valve to chlorine tower.
9. Install flex air hose.
10. Open valves that will allow the air to force the chlorine back into the tank car.
11. Wait five minutes.
12. Close valve on chlorine tank car.
13. Close valves and then crack open slightly. Loosen ammonia coupling and test with ammonia gas until no chlorine gas is escaping.
14. Remove chlorine flex line.
15. Reassemble and cap chlorine flex line and verify that no air is escaping.
16. Close tank car valve farthest from the chlorine tower.
17. Remove gage assembly slowly and test with ammonia gas. Put cap on gage assembly.
18. Put plugs back in chlorine tank car valves and secure lid.

DON'T LEAVE VALVE HANDLE IN CHLORINE TANK CAR

19. Close valves.
20. Remove flex air hose.
21. Store all gear and lock tool cabinet.
22. Raise and lock draw bridge.
23. Change Department of Transportation placards to read "danger chlorine empty."
24. Place warning light and sign at the end of the spur.
25. Place wheel chocks at the end of the spur.
26. Unlock and open derailing mechanism.
27. Remove compressor tag.
28. Verify that valves are properly tagged.
29. Call railroad and notify them to pick up empty tank car.
30. Record name of railroad official contacted.
31. Record date and time of disconnect on log sheet.
32. Sign Bill of Lading.
33. Sign name on log sheet to indicate that job is completed.

10.42 Chlorine Leaks

Chlorine leaks must be taken care of immediately or they will become worse.

Corrective measures should be undertaken only by trained operators wearing proper safety equipment. All operators should be trained to safely repair chlorine leaks.

All other persons should leave the danger area until conditions are safe again.

If the leak is large, all persons in the adjacent areas should be warned and evacuated. Obtain police help. You must always consider your neighbors . . . PEOPLE, animals, and plants.

1. *BEFORE ANY NEW SYSTEM IS PUT INTO SERVICE*, it should be cleaned, dried, and tested for leaks. Pipelines may be cleaned and dried by flushing and steaming from the high end to allow condensate and foreign materials to drain out. After the empty line is heated thoroughly, dry air may be blown through the line until it is dry. After drying, the system may be tested for tightness with 150 psi (10.5 kg/sq cm) dry air. Leaks may be detected by application of soapy water to the outside of joints. Small quantities of chlorine gas may now be introduced into the line, the test pressure built up with air, and the system tested for leaks. Whenever a new system is tested for leaks, at least one chlorinator should be on the line to withdraw chlorine from the system in case of a leak. The same is true in case of an emergency leak at any installation. If a chlorinator is not running, at least one or more should be started. Preferably, all available chlorinators should be put on the line.

2. *TO FIND A CHLORINE LEAK*, tie a rag on a stick, *DIP THE RAG*[35] in a strong ammonia solution, and hold the rag near the suspected points. White fumes will indicate the exact location of the leak. Location of leaks by this method may not be possible for large leaks which diffuse the gas over large areas. Do not use an ammonia spray bottle because the entire room could turn white if it is full of chlorine gas.

3. *IF THE LEAK IS IN THE EQUIPMENT* in which chlorine is being used, close the valves on the chlorine container at once. Repairs should not be attempted while the equipment is in service. All chlorine piping and equipment that is

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[35] *A one-inch (2.5 cm) paint brush may be used instead of a rag.*

to be repaired by welding should be flushed with water or steam. Before returning equipment to use, it *MUST* be cleaned, dried, and tested as previously described.

4. *IF THE LEAK IS IN A CHLORINE CYLINDER OR CONTAINER*, use the emergency repair kit supplied by most chlorine suppliers. These kits can be used to stop most leaks in a chlorine cylinder or container and can usually be delivered to a plant within a few hours if one is not already at the site of the leak. *IT IS ADVISABLE TO HAVE EMERGENCY REPAIR KITS AVAILABLE AT YOUR PLANT AT ALL TIMES AND TO TRAIN PERSONNEL IN THEIR USE.* Location of such kits should be posted outside chlorine storage areas.
5. If chlorine is escaping as a liquid from a cylinder or a ton tank, turn the container so that the leaking side is on top. In this position, the chlorine will escape only as a gas, and the amount which escapes will be only 1/15 as much as if the liquid chlorine were leaking. Keeping the chlorinators running also will reduce the amount of chlorine gas leaking out of a container. Increase the feed rate to cool the supply tanks as much as possible.
6. *FOR SITUATIONS IN WHICH A PROLONGED OR UNSTOPPABLE LEAK* is encountered, emergency disposal of chlorine should be provided. Chlorine may be absorbed in solutions of caustic soda, soda ash, or agitated hydrated lime slurries (Table 10.2). Chlorine should be passed into the solution through an iron pipe or a properly weighted rubber hose to keep it immersed in the absorption solution. The container should not be immersed because the leaks will be aggravated due to the corrosive effect, and the container may float when partially empty. In some cases it may be advisable to move the container to an isolated area. Discuss the details of such precautions with your chlorine supplier.
7. *NEVER PUT WATER ON A CHLORINE LEAK.* A mixture of water and chlorine will increase the rate of corrosion of the container and make the leak larger. Besides, water may warm the chlorine, thus increasing the pressure and forcing the chlorine to escape faster.
8. *LEAKS AROUND VALVE STEMS* can often be stopped by closing the valve or tightening the packing gland nut. Tighten the nut or stem by turning it clockwise.
9. *LEAKS AT THE VALVE DISCHARGE OUTLET* can often be stopped by replacing the gasket or adapter connection.
10. *LEAKS AT FUSIBLE PLUGS AND CYLINDER VALVES* usually require special handling and emergency equipment. Call your chlorine supplier immediately and obtain an emergency repair kit for this purpose if you do not have a kit readily available.
11. *PIN HOLE LEAKS* in the walls of cylinder and ton tanks can be stopped by using a clamping pressure saddle with a turn-buckle available in repair kits. This is only a temporary measure, and the container must be emptied as soon as possible.

    If a repair kit is not available, use your ingenuity. One operator stopped a pin hole leak temporarily until a repair kit arrived by placing several folded layers of neoprene packing over a leak, a piece of scrap steel plate over the packing, wrapping a chain around the cylinder and steel plate, and applying leverage pressure with a crowbar.
12. *A LEAKING CONTAINER* must not be shipped. If the container leaks or if the valves do not work properly, keep the container until you receive instructions from your chlorine supplier for returning it. If a chlorine leak develops in transit, keep the vehicle moving until it reaches an open area.
13. Do not accept delivery of containers showing evidence of leaking, stripped threads, or abuse of any kind.
14. If a chlorine container develops a leak, be sure your supplier does not charge you for the unused chlorine.
15. Chlorine leaks may be detected by sniffleators and other detection devices. Alarm systems may be connected to these devices. Be sure to follow manufacturer's recommendations regarding frequency of checking and testing detection devices and alarm systems.

TABLE 10.2 CHLORINE ABSORPTION SOLUTIONS*

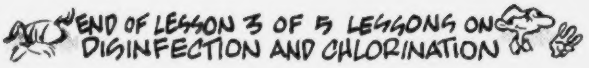
Absorption Solution		Alkali (lb)	Water (gal)
Caustic Soda (100%)	a	125	40
	b	188	60
	c	2500	800
Soda Ash	a	300	100
	b	450	150
	c	6000	2000
Hydrated Lime**	a	125	125
	b	188	188
	c	2500	2500

Chlorine Container Size (lb net):
a = 100, b = 150, c = 2000

QUESTION

Write your answer in a notebook and then compare your answer with the one on page 390.

10.4C How would you look for a chlorine leak?


END OF LESSON 3 OF 5 LESSONS ON DISINFECTION AND CHLORINATION

Please answer the discussion and review questions before continuing with Lesson 4.

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* Source: The Chlorine Institute.

** Hydrated lime solution must be continuously and vigorously agitated while chlorine is to be absorbed.

DISCUSSION AND REVIEW QUESTIONS

Chapter 10. DISINFECTION AND CHLORINATION

(Lesson 3 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 2.

14. What type of breathing apparatus should be worn when entering an area in which chlorine gas is present?
15. Why should clothing be removed from a person who has been in an area contaminated with liquid or gaseous chlorine?
16. How could your police department assist you in the event of a serious chlorine leak?
17. Why should chlorine containers and cylinders be stored where they won't be heated?
18. Why are slings used to hold chlorine tubing when changing chlorine cylinders?
19. Why should water never be poured on a chlorine leak?
20. How would you attempt to repair a pin hole leak in a chlorine cylinder?

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 4 of 5 Lessons)

10.5 CHLORINATION EQUIPMENT AND MAINTENANCE (by J.L. Beals)

10.50 Chlorinators

Chlorine usually is delivered by vacuum-solution feed chlorinators (Figs. 10.13 and 10.14). The chlorine gas is controlled, metered, introduced into a stream of injector water, and then conducted as a solution to the point of application.

The primary advantage of vacuum operation is safety. If a failure or breakage occurs in the vacuum system, the chlorinator either stops the flow of chlorine into the equipment or allows air to enter the vacuum system rather than allowing chlorine to escape into the surrounding atmosphere. In case the chlorine inlet shutoff fails, a vent valve discharges the incoming gas to the outside of the chlorinator building.

The operating vacuum is provided by a hydraulic injector. The injector operating water absorbs the chlorine gas, and the resultant chlorine solution is conveyed to a chlorine diffuser through corrosion-resistant conduit.

A vacuum chlorinator also includes a vacuum regulating valve to dampen fluctuations and give smooth operation. A vacuum relief prevents excessive vacuum within the equipment.

A typical vacuum control chlorinator is shown in Figs. 10.13 and 10.14 and the purposes of the parts are listed in Table 10.3. Chlorine gas flows from a chlorine container to the gas inlet (see Fig. 10.14). After entering the chlorinator the gas passes through a spring-loaded pressure regulating valve which maintains the proper operating pressure. A rotameter is used to indicate the rate of gas flow. The rate is controlled by a V-notch variable orifice. The gas then moves to the injector where it is dissolved in water and leaves the chlorinator as a chlorine solution (HOCl) ready for application.

10.51 Evaporators

Chlorine evaporators are installed in treatment plants where large quantities of chlorine are used. An evaporator (Fig. 10.15) is a hot water heater surrounding a steel tank. Water is usually heated by electricity. Heat in the water is transferred to the liquid chlorine in an inner steel tank. Water bath heaters are used to provide an even distribution of heat around the center tank to eliminate the problem of hot spots on the inner tank. Elimination of hot spots makes the evaporator easier to control and reduces the danger of overheating the chlorine and causing pressurization of chlorine by expansion.

Liquid chlorine containers are connected to the chlorine system through the liquid valve. When the liquid chlorine flowing from the container reaches the evaporator, the liquid chlorine vaporizes. The temperature of the chlorine gas is around 110 to 120°F (43 to 49°C). Chlorine gas flows from the evaporator to the gas manifold. Chlorine gas manifolds have gas filters to remove small particles from the gas.

When the temperature of the water in the evaporator water jacket reaches a preset level, valves operate (open and close) to allow chlorine gas to flow to the chlorinators. If the water temperature falls below the set point, a valve closes to prevent the carry-over of liquid chlorine to the chlorinator.

The level of liquid chlorine in the evaporator tank is automatically regulated by pressure from the chlorination system demand for chlorine. When the chlorine demand is high, pressure at the liquid chlorine supply containers exceeds the evaporator gas pressure and liquid chlorine flows into the inner tank. As the chlorine demand decreases, the evaporator's inner-tank chlorine gas pressure increases from the vaporization of the liquid chlorine. This increased pressure reduces the liquid chlorine flow into the evaporator. Equilibrium usually is obtained when the liquid flow rate and rate of vaporization are equal.

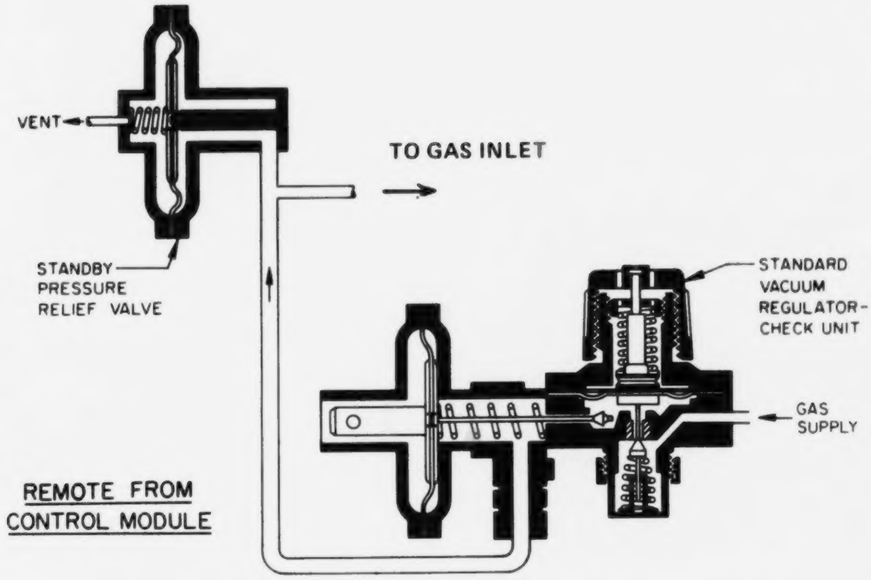
VENT
TO GAS INLET
STANDBY PRESSURE RELIEF VALVE
STANDARD VACUUM REGULATOR-CHECK UNIT
GAS SUPPLY
REMOTE FROM CONTROL MODULE

Fig. 10.13 Chlorinator gas pressure controls
(Permission of Wallace & Tiernan Division, Penwalt Corporation)

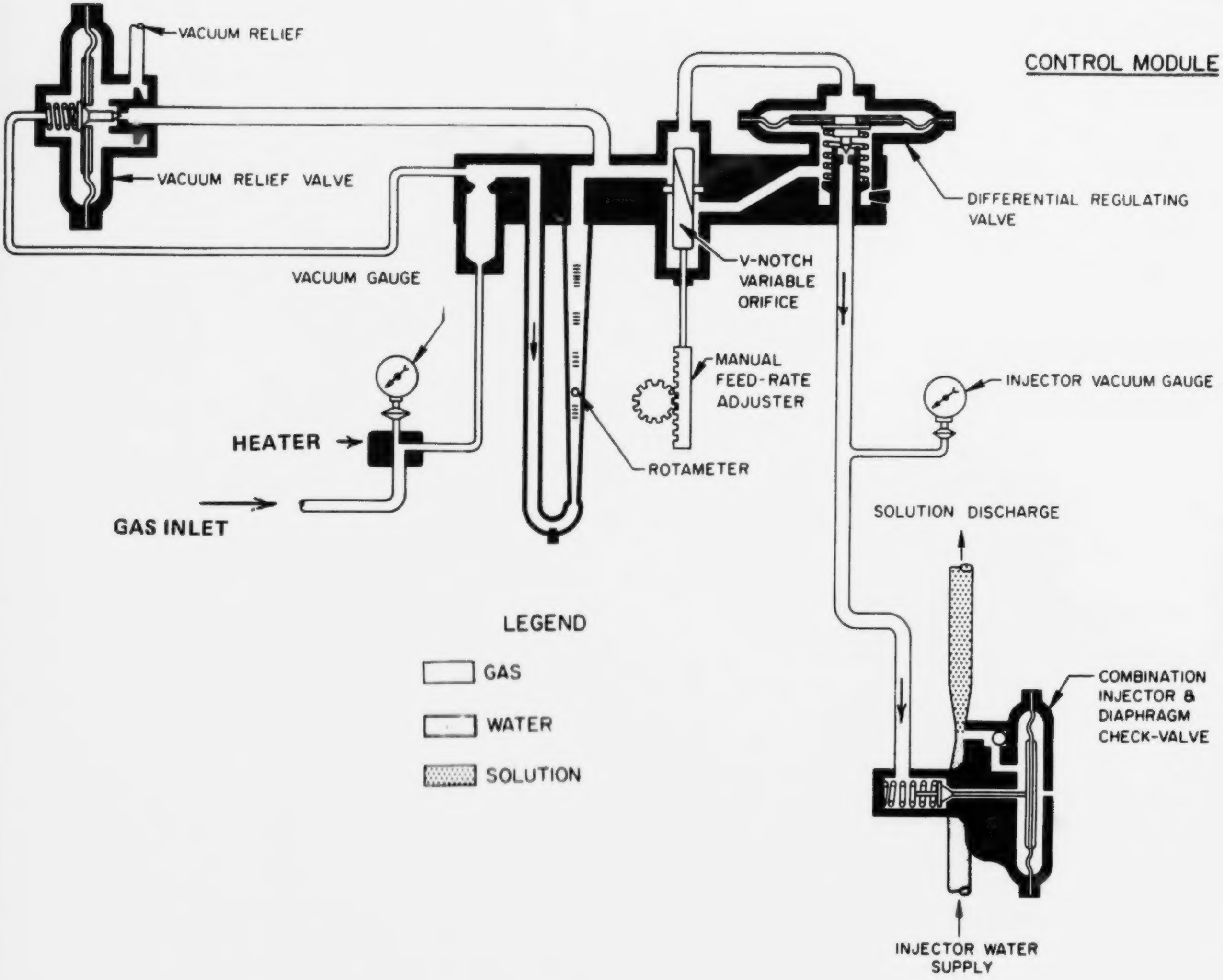
VACUUM RELIEF
CONTROL MODULE
VACUUM RELIEF VALVE
DIFFERENTIAL REGULATING VALVE
VACUUM GAUGE
V-NOTCH VARIABLE ORIFICE
MANUAL FEED-RATE ADJUSTER
INJECTOR VACUUM GAUGE
HEATER
ROTAMETER
GAS INLET
SOLUTION DISCHARGE
LEGEND
GAS
WATER
SOLUTION
COMBINATION INJECTOR & DIAPHRAGM CHECK-VALVE
INJECTOR WATER SUPPLY

Fig. 10.14 Vacuum-solution feed chlorinator

(Permission of Wallace & Tiernan Division, Penwalt Corporation)

TABLE 10.3 CHLORINATOR PARTS AND PURPOSE

(Figures 10.13 and 10.14)

Part	Purpose
1. Pressure Gage (Not shown on Fig. 10.13)	Indicates chlorine gas pressure at chlorinator system from chlorine manifold and supply (20 psi minimum and 40 psi maximum or 2.4 kg/sq cm minimum and 4.8 kg/sq cm maximum).
2. Gas Supply	Provides source of chlorine gas from containers to chlorinator system.
3. Vacuum Regulator-check Unit	Maintains a constant vacuum on chlorinator.
4. Standby Pressure Relief	Relieves excess gas pressure on chlorinator.
5. Vent	Discharges any excess chlorine gas (pressure) to atmosphere outside of chlorination building.
6. Gas Inlet	Allows entrance of chlorine gas to chlorinator. Gas flows from chlorine container through supply line and gas manifold to inlet.
7. Heater	Prevents *RELIQUEFACTION*[36] of chlorine gas.
8. Vacuum Gage	Indicates vacuum on chlorinator system.
9. Rotameter Tube and Float	Indicate chlorinator feed rate by reading top of float or center of ball for rate marked on tube.
10. Differential Regulating (Reducing) Valve	Regulates (reduces) chlorinator chlorine gas pressure. Serves to maintain a constant differential across the orifice in order to obtain repeatable chlorine gas flow rates at a given V-notch orifice opening regardless of fluctuations in the injector vacuum.
11. V-notch Plug and Variable Orifice	Control chlorine feed rate by regulating flow of chlorine gas. A wide V-notch in the plug allows high feed rates through the orifice and a small V-notch in the plug provides low feed rates.
12. Vacuum Relief Valve	Relieves excess vacuum by allowing air to enter system and reduce vacuum.
13. Vacuum Relief	Provides source of air to reduce excess vacuum.
14. Injector Vacuum Gage	Indicates vacuum at the injector.
15. Diaphragm Check-valve	Regulates chlorinator vacuum which in turn adjusts chlorinator feed rate. Receives signal from chlorine feed rate controls and then adjusts feed rate by regulating vacuum.
16. Manual Feed-rate Adjuster	Regulates chlorine feed rate manually. Most chlorination systems have automatic feed-rate controls with a manual override.
17. Injector Water Supply	Provides source of water for chlorine solution. Must provide sufficient pressure and volume to operate injector.
18. Injector	Mixes or injects chlorine gas into water supply. Creates sufficient vacuum to operate chlorinator and to pull metered amount of chlorine gas.
19. Solution Discharge	Discharges solution mixture of chlorine and water.

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[36] *Reliquefaction (re-LICK-we-FACK-shun). The return of a gas to a liquid. For example, a condensation of chlorine gas returning to a liquid form.*

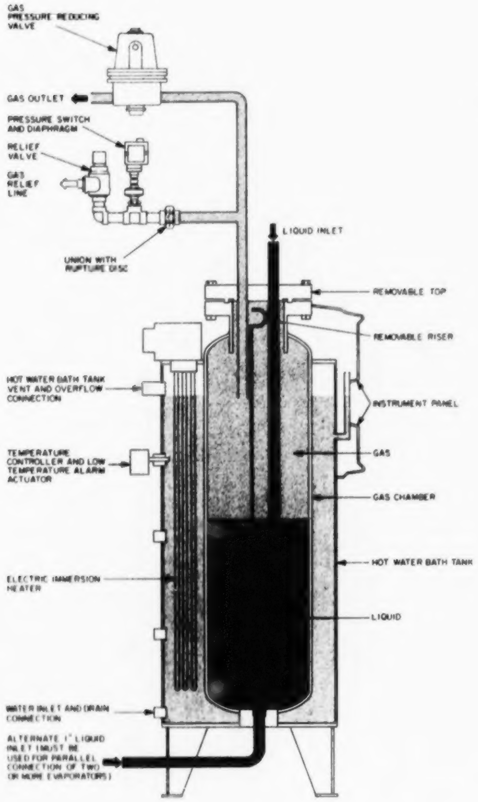
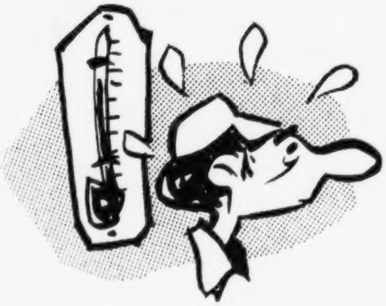

GAS PRESSURE REDUCING VALVE
GAS OUTLET
PRESSURE SWITCH AND DIAPHRAGM
RELIEF VALVE
GAS RELIEF LINE
UNION WITH RUPTURE DISC
LIQUID INLET
REMOVABLE TOP
REMOVABLE RISER
HOT WATER BATH TANK VENT AND OVERFLOW CONNECTION
INSTRUMENT PANEL
TEMPERATURE CONTROLLER AND LOW TEMPERATURE ALARM ACTUATOR
GAS
GAS CHAMBER
HOT WATER BATH TANK
ELECTRIC IMMERSION HEATER
LIQUID
WATER INLET AND DRAIN CONNECTION
ALTERNATE 1" LIQUID INLET (MUST BE USED FOR PARALLEL CONNECTION OF TWO OR MORE EVAPORATORS)

Fig. 10.15 Evaporator

(Permission of Wallace & Tiernan Division, Penwalt Corporation)

When chlorine gas leaves the evaporator and passes through the gas pressure-reducing valve, the chlorine gas enters the inlet block on the chlorinator. The chlorinator meters the chlorine gas at the desired dosage rate to the injector. A heater at the chlorinator inlet block vaporizes any liquid droplets that may have carried over from the evaporator. Try to keep the chlorinator room 10°F (6°C) warmer than the storage or evaporator room to prevent reliquefaction of chlorine gas back to liquid chlorine.



10.52 Hypochlorinators (hi-poe-KLOR-i-NAY-tors)

"Hypochlorinators" are chlorine pumps or devices used to feed chlorine solutions made from hypochlorites such as bleach (sodium hypochlorite) or calcium hypochlorite. Hypochlorite compounds are available as liquids or various forms of solids (powder, pellets), and in a variety of containers or in bulk. Hypochlorination systems consist of a water meter and a diaphragm metering pump. The pump feeds a hypochlorite solution in proportion to the wastewater flow.

10.53 Chlorine Dioxide Facility (Fig. 10.16)

Most existing chlorination units may be used to produce chlorine dioxide. In addition to the existing chlorination system, a diaphragm pump, solution tank, mixer, chlorine dioxide generating tower and electrical controls are needed. The diaphragm pump and piping must be made of corrosion resistant materials because of the corrosive nature of chlorine dioxide. Usually PVC or polyethylene pipe is used.

Special consideration must be given when handling sodium chlorite. Sodium chlorite is usually supplied as a salt and is very combustible around organic compounds. Whenever spills occur, sodium chlorite must be neutralized with anhydrous sodium sulfite. Combustible materials (including gloves) should not be worn when handling sodium chlorite. If sodium chlorite comes in contact with clothing, the clothes should be removed immediately and soaked in water to remove all traces of sodium chlorite or they should be burned immediately. Due to the hazards of safely handling sodium chlorite, chlorine dioxide has not been widely used to treat wastewater.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 390.

10.5A How is chlorine delivered (fed) to the point of application?

10.5B Why has chlorine dioxide not been widely used to treat wastewater?

10.54 Installation and Maintenance

The following are some features of importance when working with chlorine facilities. Also examine these items when reviewing plans and specifications.

1. Chlorinators should be located as near point of application as possible.
2. If possible, there should be a separate room for chlorinators and chlorine container storage (above ground) to prevent chlorine gas leaks from damaging equipment and harming personnel. There should be no access to this room from a room containing equipment or where personnel work.
3. Ample working space around the equipment and storage space for spare parts should be provided.
4. There should be an ample supply of water to operate chlorinator at required capacity under maximum pressure conditions at the chlorinator injector discharge.
5. The building should be adequately heated. The temperature of the chlorine cylinder and chlorinator should be above 50°F (10°C). Line heaters may be used to keep chlorine piping and chlorinator at higher temperatures to prevent condensing of gas into liquid in the pipelines and chlorinator. The maximum temperature at which a chlorine cylinder is stored should not exceed 100°F (43°C).
6. It is not advisable to draw more than one pound of chlorine per °F (0.8 kg/°C) *AMBIENT TEMPERATURE*[37] from any one 100- to 150-pound (45 and 68 kg) cylinder in a 24-hour period because of the danger of freezing and slowing up the chlorine flow. With ton containers, the limit of chlorine gas is about 8 pounds of chlorine per day per °F (6.4 kg/°C) ambient temperature. When evaporators are provided, these limitations do not apply.
7. There should be adequate light.
8. There should be adequate ventilation. Continuous ventilation is desirable. Forced ventilation must be provided to remove gas if a large leak develops. The outlet of a forced ventilation system must be near the floor because chlorine is 2.5 times heavier than air. Use a pressurized fan (keep room under slight positive pressure). Do not suck air from the room through the fan, because chlorine gas can damage the fan motor. Louvers or vents should swing out and always be open, or open automatically. It should be impossible to lock the louvers shut.
9. Adequate measuring and controlling of chlorine dosage is required. Scales and recorders indicating loss in weight are desirable as a continuous check and as a record of the continuity of chlorination. *RECORD* weights daily.
10. There should be continuity of chlorination. When chlorination is practiced for disinfection, it is needed continuously for the protection of downstream water users. Therefore, arrange that chlorination will function for 1440 minutes per day. To secure continuous chlorination, the chlorine gas lines from cylinders should feed to the manifold so that the cylinders can be removed without interrupting feed of gas. Duplicate units with automatic cylinder switchover should be provided. Hypochlorinators are sometimes used during emergencies.
11. For additional information on chlorinator maintenance, refer to Chapter 15, "Maintenance."

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[37] *Ambient Temperature (AM-bee-ent). Temperature of the surroundings.*

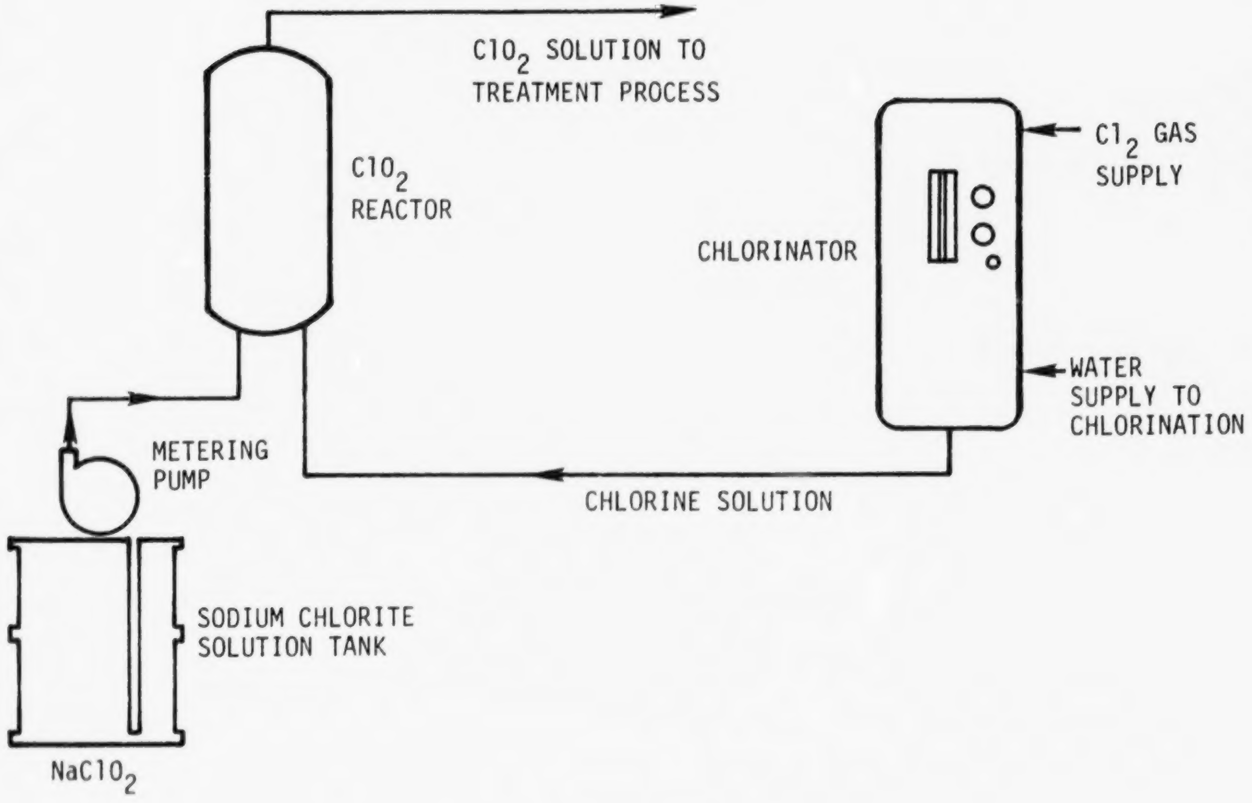

ClO_2 SOLUTION TO TREATMENT PROCESS
ClO_2 REACTOR
CHLORINATOR
Cl_2 GAS SUPPLY
WATER SUPPLY TO CHLORINATION
METERING PUMP
CHLORINE SOLUTION
SODIUM CHLORITE SOLUTION TANK
$NaClO_2$

Fig. 10.16 Chlorine dioxide facility

Source: *AN ASSESSMENT OF OZONE AND CHLORINE DIOXIDE TECHNOLOGIES FOR TREATMENT OF MUNICIPAL WATER SUPPLIES, EXECUTIVE SUMMARY.* U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, EPA-600/8-78-018, October 1978.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 390 and 391.

10.5C Why should chlorinators be in a separate room?

10.5D Why is room temperature important for proper chlorinator operation?

10.5E Why should not more than one pound of chlorine per day per °F (0.8 kg/°C) ambient temperature be drawn from any one cylinder?

10.5F Why is adequate ventilation important in a chlorinator room?

10.5G How can chlorinator rooms be ventilated?

10.5H How can chlorination rates be checked against the chlorinator setting?

10.5I Why should chlorination be continuous?

10.5J How can continuous chlorination be achieved?

10.55 Installation Requirements

(Portions of these paragraphs are from Section A of Wallace & Tiernan Catalog Sheet Nos. 5.110 and 5.111. They are reproduced with the permission of Wallace & Tiernan Division, Penwalt Corporation)

10.550 Piping, Valves and Manifolds

After you have determined (a) the availability of various types of chlorine containers and selected the type most suited to your particular needs, (b) the inventory required and the space needed, (c) the method of handling the containers, and (d) the type of weighing scales to be used, the final step in regard to chlorine supply is to plan the required piping.

CONNECTIONS AT CONTAINERS: Standard practice is to connect an auxiliary tank valve (either union- or yoke-type) to the container valve to facilitate changing containers, to minimize the release of gas when containers are changed, and to serve as a shut-off valve in the event the container valve is defective. From this auxiliary valve a flexible connection is used to connect to the manifold or, in the case of small installations, directly to the chlorinator.

CONNECTIONS AT CHLORINATOR: In general, small chlorinators are equipped to receive a flexible connection directly from the chlorine container and no other piping is necessary. Larger chlorinators may use a flexible connection from a manifold, if located close to the container, or may employ piping from the manifold to the chlorinator where the distance is greater.

CONNECTIONS AT EVAPORATOR: Where evaporators are used, the piping from the manifold to the evaporator carries liquid chlorine. The piping from the evaporator to the chlorinator carries chlorine gas. Evaporators normally are furnished with all necessary immediate valves and fittings.

PIPING — MATERIALS AND JOINTS: Best practice calls for the use of seamless carbon steel (Schedule 80) pipe for conducting chlorine gas or liquid and fittings that are 3000 lb forged steel. Except in unusual cases, the size will be 3/4 or 1 inch (1.9 to 2.5 cm). In most installations, it will be found practical to use threaded joints. These joints should be put together using teflon tape as a joint lubricant. Unions of the flanged, ammonia type, two-bolt oval are recommended. For pipe sizes larger than one inch (2.5 cm) in diameter, a four-bolt oval should be used. From the standpoint of maintenance, line valves should be kept to a minimum. Insulation is required only in those unusual cases where it is necessary to prevent chlorine gas lines from becoming chilled or liquid lines from becoming overheated.

PIPING — CHLORINE GAS: It is important to observe the correct temperature conditions in conducting chlorine gas from the location of the containers to the point of use. To avoid difficulty with reliquefaction of chlorine, piping and control equipment should be at a higher temperature than that of the chlorine containers. In general, a difference of 5 to 10°F (3 to 6°C) is recommended. It is preferable to run chlorine gas lines overhead through relatively warm areas rather than along the floor or through basement areas where lower temperatures may be encountered.

When it is not possible to secure suitable temperature conditions, the use of an external chlorine-pressure reducing valve near the containers is recommended.

The use of a chlorine-pressure reducing valve is also recommended in those localities where severe temperature changes are likely to be encountered during a 24-hour period.

PIPING — LIQUID CHLORINE: In the case of liquid chlorine, it is important to avoid conditions that will encourage vaporization. Thus it is important to keep liquid chlorine lines as cool as, or cooler than, the containers. Avoid running liquid chlorine lines through overheated areas where gasification is likely to take place.

Valves in liquid chlorine lines should be kept to a minimum. This is particularly important to avoid situations where it is easy to close two valves in a line thus trapping liquid which, upon an increase in temperature, may develop dangerous pressures.

The use of an expansion chamber is recommended where traps occur in the line or where it is necessary to run lines a considerable distance. As the name implies, the chamber provides an area for expansion in the event that valves at both ends of the line are closed.

VALVES AND MANIFOLDS: Chlorine valves consist of the following: (a) auxiliary tank valves for use at the container, (b) header valves for use on or in conjunction with manifolds, (c) line valves for insertion in liquid and gas lines for shut-off purposes, and (d) pressure reducing valves to reduce the pressure in gas lines where necessary. Manifolds are assemblies designed to receive the flexible connections from the container, generally provide a shutoff valve, and include the means of connecting to the chlorinator piping. They are available in types and sizes to accommodate any required number of containers and may be mounted in any convenient manner.

10.551 Chlorinator Injector Water Supply

The injector operating water supply serves to produce the vacuum under which vacuum chlorinators function and to dissolve the chlorine and discharge it as a solution at the point of application. The quantity of water required and the minimum pressure at which it is supplied depend upon:

1. Maximum chlorinator feed rate, and
2. Back pressure at injector discharge (pressure at point of chlorine application, plus friction loss in solution line, and plus or minus elevation differences between injector and point of application).

Water quantity and pressure can vary from one to two gpm (4.5 to 11 cu m/day) at 15 psi (1 kg/sq cm) (for 10 lbs/day (4.5 kg/day) at 0 back pressure) and up to 360 gpm (1960 cu m/day) at 60 psi (4 kg/sq cm) (8000 lbs/day (3630 kg/day) at 20 psi (1.4 kg/sq cm) back pressure). In some extremely high back pressure situations, injector water up to 300 psi (21 kg/sq cm) may be required. These conditions do not occur often in wastewater treatment installations, and back pressures exceeding 20 psi (1.4 kg/sq cm) (except in force-main application) are uncommon.

Plant effluent is used frequently as injector operating water. When this is the case, a pump is usually required to provide the required quantity and pressure. If a pump is used exclusively for injector operation, it should be designed for 25 to 50 percent overcapacity to allow for wear. Injector water is often supplied from a service water system also providing water for other purposes. If a potable water supply is the only source of injector water, precautions must be taken to insure against direct cross-connections between wastewater and potable water to prevent contamination of the potable water. (Consult your local public health authority.)

Injector water requirements vary so widely depending upon make, model, capacity, and back pressure that it is advisable to consult the chlorinator manufacturer if a new system is to be installed or if an existing system must be altered and any of these operating conditions are to be changed.

10.56 Review of Plans and Specifications

See the previous two sections, 10.54 and 10.55, for items that should be considered when reviewing plans and specifications.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 391.

10.5K What is the best piping material for conducting chlorine gas or liquid?

10.5L Plant ______________ is used frequently as the chlorinator injector water supply.

10.6 OTHER USES OF CHLORINE

10.60 Odor Control

Chlorination is used to inhibit the growth of odor-producing bacteria and to destroy hydrogen sulfide (H_2S), the most common odor nuisance, which has the smell of rotten eggs. Hydrogen sulfide, in addition to creating an odor nuisance, can be an explosion hazard when mixed with air in certain concentrations. Breathing H_2S can impair your ability to smell, and too much will paralyze your respiratory center, causing death in severe cases. It also can cause corrosion of metals and concrete, being particularly damaging to electrical equipment even in low concentrations.

The presence of hydrogen sulfide may be found in significant quantities in any collection and treatment system where sufficient time is allowed for its development. It may be expected to be present most often in new systems where flows are extremely low in comparison with design capacity, and particularly in lift stations where pump operating cycles may be at a low frequency. Collection systems which serve large areas often allow time for H_2S development even when operating at design capacity.

The purpose of this section is not to discuss the reasons for odor production, but rather their elimination or control by chlorination; however, the correction of an odor problem will usually require a decision being made between system modification and treatment. Sometimes both may be required. Choices of this type often hinge on the costs involved, and it will frequently be found that modifications to major system components are far more costly than treatment. When this is the case, chlorination is usually the most economical solution. Other solutions include the use of air or ozone.

Sulfide compounds and gases develop whenever given time to do so. The rate of sulfide production increases with temperature (about 7 percent on the average with each 1°C increase in wastewater temperature).

Hydrogen sulfide odors can be inactivated by chlorination at levels well below the chlorine demand point. This is commonly referred to as "sub-residual chlorination." The reason that this is true is based on the fact that the $Cl_2 + H_2S$ reaction precedes most other chlorine-consuming reactions. Since it is known that bacterial kills occur at sub-residual levels, it is logical that odor-producing bacteria can be reduced in numbers without satisfying the chlorine demand. This can be accomplished without significantly interfering with organisms beneficial to the treatment processes.

The quantities of chlorine required to accomplish control of odors vary widely from plant to plant and at any given plant fluctuate over a broad range. Hydrogen sulfide is generally found in higher concentrations when flows are low. For this reason it is usually not economical to chlorinate for odor control in direct proportion to flow. To establish a basis for treatment, tests should be run over periods which include all the various conditions which could possibly affect odor production.

When the requirements are known, the primary concern is to apply chlorine at the proper location. The best locations are generally up-sewer ahead of the plant influent structures, and up-sewer ahead of lift stations. This is done to allow mixing and reaction time before the waste reaches a point of agitation.

Sometimes force mains empty into the gravity sections of a collection system several hours after pumping. If odor problems result, a treatment point should be placed upstream at a point where the sewer is still under pressure and flowing full; thus treatment can be completed before odors are released to the atmosphere.

Hydrogen sulfide should not be considered merely an odor nuisance. Always keep in mind that it can create an explosion hazard, it can paralyze your respiratory center, and it should always be considered a source of corrosion. For these reasons, odor masking agents should not be used except possibly as additional treatment for odors not eliminated by chlorination. Excessive use of masking agents could prevent detection of a serious problem condition.

10.61 Protection of Structures

The destruction of hydrogen sulfide in wastewater also reduces the production of sulfuric acid that is highly corrosive to sewer systems and structures. This is particularly significant where temperatures are high and time of travel in the sewer system is unusually long. The treatment is similar to that for odor control: chlorination sufficient to prevent hydrogen sulfide formation or to destroy hydrogen sulfide that has been produced (about 2 mg/*L* chlorine per mg/*L* of hydrogen sulfide). Sulfide problems also may be corrected by oxygenation in sewers. The choice between oxygenation and chlorination will usually depend on the costs and safety risks involved. Chlorination is effective and cheaper than oxygenation, but chlorine leaks can be a serious hazard to the public.

10.62 Aid to Treatment

Among its many uses, chlorine improves treatment efficiency in the following ways.

10.620 Sedimentation and Grease Removal

Prechlorination at the inlet of a settling tank improves clarification by improving settling rate, reducing *SEPTICITY*[38] of raw wastewater, and increasing grease removal. Maximum grease removal is achieved when chlorination is combined with aeration ("aerochlorination"). This is an expensive procedure, and some studies have indicated that benefits are minimal. Generally, grease removal in this manner is considered a beneficial side effect or "bonus" reaction to chlorine which is essentially applied for other reasons. Excess chlorination ahead of secondary processes can inhibit the bacterial action critical to the process and decrease sedimentation efficiency.

10.621 Trickling Filters

Continuous chlorination at the filter influent controls slime growths and destroys filter fly larvae (Psychoda). Generally the chlorine is applied to produce a residual of 0.5 mg/*L* (continuous) at the orifices or nozzles. Caution should be used because some filter growth may be severely damaged by excessive chlorination. Suspended solids will increase in a trickling filter effluent after chlorination for filter fly control. Also, it will be difficult to evaluate filter performance on the basis of BOD removals because chlorine can interfere with the BOD test. As a general statement, it would be well to look closely at loadings, operation, and general adequacy of the process when filter fly chlorination is continuously necessary, because continuous chlorination may be an expensive alternative for adequate design and operation.

10.622 Activated Sludge

Chlorination of return sludge reduces bulking of activated sludge that is caused by overloading. The point of application should be where the return sludge will be in contact with the chlorine solution for about one minute before the sludge is mixed with the incoming settled wastewater. Chlorine is also commonly used to control *FILAMENTOUS ORGANISMS*.[39] Again, chlorine used in this manner is an expensive alternative for adequate design and operation. The main effort should be directed toward process improvement, considering chlorination mainly as an emergency solution. Never forget that chlorine is toxic to organisms that are needed to treat the incoming wastes.

10.623 Reduction of BOD

The reduction of BOD by chlorination has been explored by numerous investigators. These individuals have proposed four types of reactions to explain the reduction of BOD level.

1. Direct oxidation.
   Chlorine is an oxidizing agent and directly oxidizes the wastes instead of the organisms.
2. Formation with nitrogen compounds of bactericidal chloramines by substitution of chlorine for hydrogen.
3. Formation with carbon compounds of substances that are no longer decomposable by substitution of chlorine for hydrogen.
4. Addition of chlorine to unsaturated compounds to form non-decomposable substances.

These investigators have demonstrated that chlorination of raw wastewater can produce the following effects.

1. Reduce BOD by at least 2 mg/*L* for each mg/*L* of chlorine absorbed up to the point at which a residual is produced.
2. The reduction is increased with increasing chlorine dosages. This addition is not without limits.
3. The reduction seems to be permanent.

QUESTIONS

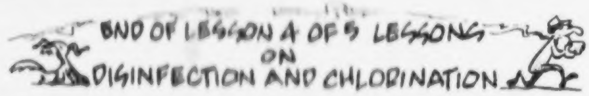
Write your answers in a notebook and then compare your answers with those on page 391.

10.6A How can hydrogen sulfide odors be controlled? Why?

10.6B How can sulfuric acid damage to structures be minimized or eliminated? Why?

10.7 ACKNOWLEDGMENTS

Portions of the information contained in this chapter were taken in part from Chapter 17, "Disinfection and Chlorination," Water Pollution Control Federation *MANUAL OF PRACTICE NO. 11*; and from Chapter 7, "Chlorination of Sewage," *MANUAL OF INSTRUCTION FOR SEWAGE TREATMENT PLANT OPERATORS* (New York Manual). Both publications are excellent references for additional study. Mr. J.L. Beals provided many helpful comments.



Please answer the discussion and review questions before continuing.

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[38] *Septicity (sep-TIS-it-tee). Septicity is the condition in which organic matter decomposes to form foul-smelling products associated with the absence of free oxygen. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.*

[39] *Filamentous Organisms (FILL-a-MEN-tuss). Organisms that grow in a thread or filamentous form.*

DISCUSSION AND REVIEW QUESTIONS

Chapter 10. DISINFECTION AND CHLORINATION

(Lesson 4 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 3.

21. How is the rate of chlorine gas flow in a chlorinator controlled?
22. How often should the weights of chlorine cylinders be recorded?
23. Why must chlorination be continuous?
24. Why should the temperature of chlorine piping and control equipment be higher than the temperature of the chlorine containers?
25. Why must direct cross-connections between a public water supply and the injector water supply be avoided?
26. What is "sub-residual chlorination?"
27. Why should sulfide production be controlled?

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 5 of 5 Lessons)

10.8 DECHLORINATION[40]

10.80 Need for Dechlorination

Receiving waters such as streams, rivers and lakes provide habitat for fish and numerous other types of aquatic organisms. The need for protection of this environment from toxic substances (such as chlorine) has prompted regulatory agencies to require that no measurable chlorine residual be allowed to enter receiving waters in the effluents from wastewater treatment plants. Removal of chlorine from treatment plant effluents is called "dechlorination."

Dechlorination may be achieved by the following treatment processes:

1. Long detention periods. Prolonged detention periods provide sufficient time for dissipation of residual chlorine.
2. Aeration. Bubbling air through the water with a chlorine residual in the last portion of long, narrow chlorine contact basins will remove a chlorine residual.
3. Sunlight. Chlorine may be destroyed by sunlight. This is accomplished by spreading the chlorinated effluent in a thin layer and by exposing it to sunlight.
4. Activated carbon. Residual chlorine can be removed from water by absorption on activated carbon.
5. Chemical reactions. Sulfur dioxide (SO_2) is frequently used because it reacts instantaneously with chlorine on approximately a one-to-one basis (1 mg/*L* SO_2 will react with and remove 1 mg/*L* chlorine residual). Other chemicals include sodium sulfite (Na_2SO_3), sodium bisulfite ($NaHSO_3$), sodium metabisulfite ($Na_2S_2O_5$), and sodium thiosulfate ($Na_2S_2O_3$).

A chemical reaction using sulfur dioxide is the most common treatment process used to dechlorinate the effluent from treatment plants.

While high chlorine residuals (2.5 to 12.0 mg/*L*) often are required to meet the MPN coliform requirements set by the public health agencies, fish and wildlife agencies have required dechlorination to protect aquatic life in receiving waters below the plant discharge. Aquatic life, such as salmon, trout, and similar fish, can only tolerate trace (0.01 mg/*L*) amounts of chlorine.

"Dechlorination" is the physical or chemical removal of all traces of residual chlorine remaining after the disinfection process and prior to the discharge of the effluent to the receiving waters. This is commonly accomplished by the use of sulfur compounds such as sulfur dioxide, sodium sulfite or sodium metabisulfite. Activated carbon has been used, but was found to be extremely expensive in large applications.

Sulfur dioxide is the most popular method used for dechlorination to date. The reason for the popularity of sulfur dioxide is that it uses existing chlorination equipment and makes extensive training of operators unnecessary. This section will discuss the use of sulfur dioxide for dechlorination and only briefly mention other methods.

10.81 Sulfur Dioxide (SO_2)

10.810 Properties

Sulfur dioxide is a colorless gas with a characteristic pungent (sharp, biting) odor. SO_2 may be cooled and compressed to a liquid. When the gas is compressed to a liquid, a colorless liquid is formed. As with chlorine, when sulfur dioxide is in a closed container the liquid and gas normally are in equilibrium.

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[40] *Dechlorination (dee-KLOR-i-NAY-shun). The removal of chlorine from the effluent of a treatment plant.*

The pressure within the container bears a definite relation to the container's ambient temperature. This relationship is very similar to chlorine.

Sulfur dioxide is neither flammable nor explosive in either form, gas or liquid. Dry gaseous sulfur dioxide is not corrosive to most metals; however, in the presence of moisture it forms sulfuric acid (H_2SO_4) and is extremely corrosive. Due to this corrosive action, similar materials and equipment are used for the storage and application of both sulfure dioxide and chlorine. The sulfonator's diaphragms are manufactured to handle sulfur dioxide rather than chlorine.

Sulfur dioxide gas is more soluble in water than chlorine. Approximately one pound per gallon can be absorbed at 60°F (16°C). As the temperature increases, sulfur dioxide's solubility in water decreases. When dissolved in water, sulfur dioxide forms a weak solution of sulfurous acid (H_2SO_3).

The density of sulfur dioxide is very similar to chlorine; so much so, that it is possible to use a chlorine rotameter to measure the flow of sulfur dioxide gas without much difficulty. When using the chlorine rotameter, multiply the chlorine reading by 0.95 to obtain the pounds per day of sulfur dioxide used.

10.811 Chemical Reaction of Sulfur Dioxide with Wastewater

The chemical reaction of dechlorination results in the conversion of all active positive chlorine ions to the nonactive negative chloride ions. The reaction of sulfur dioxide (SO_2) with chlorine is as follows:

$$SO_2 + H_2O \rightarrow H_2SO_3 + HOCl \rightarrow H_2SO_4 + HCl.$$

The formation of sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) from this reaction is not harmful because of the small amount of acid produced. The pH of the effluent is not changed significantly unless the alkalinity is very low.

With combined chloramine,

$$NH_2Cl + H_2SO_3 + H_2O \rightarrow NH_4HSO_4 + HCl.$$

Similar reactions are formed with dichloramine and nitrogen trichloride. If some organic materials are present, the reaction rate may change so that an excess of sulfur dioxide may have to be applied. The chemical reaction between chlorine and sulfur dioxide is approximately one to one. For example, a chlorine residual of 4 mg/*L* would require a sulfur dioxide dose of 4 mg/*L*. The chemical reaction occurs almost instantaneously.

Where it may be desirable not to use sulfur dioxide for safety reasons (use of a liquid rather than toxic SO_2 gas), it may be useful to substitute sodium sulfite (Na_2SO_3) or sodium metabisulfite ($Na_2S_2O_5$). The reaction then becomes:

$$Na_2SO_3 + Cl_2 + H_2O \rightarrow Na_2SO_4 + 2\,HCl.$$

When using sodium sulfite, the reaction requires 1.78 pounds of pure sodium sulfite per pound of chlorine. The speed of reaction is similar to that of sulfure dioxide. Both sodium sulfite and sodium metabisulfite require liquid storage tanks and feed pumps, but evaporators are not needed.

10.812 Application Point

The typical application point is just prior to the discharge of the effluent to the receiving waters. This allows time for maximum disinfection of the effluent. The point of application should be where the flow is turbulent and short-circuiting should not exist. Since the dechlorination reaction requires a relatively short time period, contact basins are not needed. Often it is not feasible to have the point of application at the remote location where the effluent is discharged to the receiving waters. Since the prime consideration is the removal of chlorine residual, this removal can be accomplished at the plant site when necessary.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 391.

10.8A Why are the effluents from some treatment plants dechlorinated?

10.8B List the treatment processes that may be used to dechlorinate a plant effluent.

10.8C What happens when sulfur dioxide gas comes in contact with moisture?

10.8D The reaction of sulfure dioxide (SO_2) with chlorine produces sulfuric acid (H_2SO_4) and hydrochloric acid (HCl). Will these reactions cause a drop in the effluent pH?

10.82 Sulfur Dioxide Hazards

10.820 Exposure Responses to Sulfur Dioxide

Sulfur dioxide is extremely hazardous and must be handled with caution. Exercise extreme caution when working with sulfur dioxide, just like you would when handling chlorine.

Sulfur dioxide has a very strong, pungent odor. When you smell sulfur dioxide, notify your supervisor and get help. If qualified and authorized to do so, locate and repair the leak.

If you inhale sulfur dioxide gas, sulfurous acid will form on the moist mucous membranes in your body and cause severe irritation or more serious harm. The greater the exposure, the more serious the damage to your body. Exposure to high doses of sulfur dioxide can cause death due to lack of oxygen, chemical bronchopneumonia with severe bronchiolitis may be fatal several days later. In the event sulfur dioxide is inhaled, remove the victim to fresh air, use artificial respiration if necessary and contact a doctor. Table 10.4 summarizes the impacts of the various concentrations of sulfur dioxide on the human body.

Sulfur dioxide gas is heavier than air and, therefore, will settle in low areas. Due to its low vapor pressure, the liquid changes quickly to gas when liberated, and this gas also will settle in low areas or confined spaces.

Suitable safety equipment, similar to that used in case of chlorine leaks, must be available whenever the potential exists for contact with sulfur dioxide. Gas masks with a self-contained air supply must be readily available.

Liquid sulfur dioxide has additional hazards which are associated with any compressed or liquified gas:

1. Containers burst or safety devices activate if the liquid is overpressurized or excessively heated,
2. Violent chemical reactions result if water is sucked back into the chemical (sulfur dioxide) in the container, and
3. Body tissue freezes when in contact with a liquified gas.

TABLE 10.4 IMPACT OF SULFUR DIOXIDE ON THE HUMAN BODY

IMPACT	CONCENTRATION
Lowest concentration detectable by odor	3-5 ppm
Lowest concentration immediately irritating to throat	8-12 ppm
Lowest concentration immediately irritating to eyes	20 ppm
Lowest concentration causing coughing	20 ppm
Maximum allowable concentration for 8-hr exposure	10 ppm
Maximum allowable concentration for 1-hr exposure	50-100 ppm
Tolerable briefly	150 ppm
Immediately dangerous concentration	400-500 ppm

10.821 Detection of Leaks

The pungent odor of sulfur dioxide can be detected whenever there is a leak somewhere in the system. The location of even the smallest leak may be readily found by the use of ammonia vapor dispensed from an aspirator or squeeze bottle in the area where a leak is suspected. If the room is full of gas, an aspirator bottle will not work because the entire room could become filled with white fumes. Leaks also are detected by the use of an ammonia swab, prepared by soaking a cloth with ammonia solution. When the ammonia vapor passes the leak, a dense white fume forms. This procedure is exactly the same as that used for detecting chlorine leaks.

NEVER USE SOAPY WATER TO LOOK FOR A LEAK. WATER COMBINES WITH SULFUR DIOXIDE TO FORM SULFURIC ACID WHICH IS VERY CORROSIVE AND WILL MAKE ANY LEAK WORSE.

10.822 What to Do in Case of Leaks

The possibility of having a leak in the system is always present; therefore, be prepared for any emergency. Leaks occurring because of broken lines, broken sight glass, or leaking joints must be handled as rapidly as possible. When these emergencies occur, only authorized employees should attempt to stop a leak. If there is any question regarding the size of the leak, gas masks with a self-contained breathing apparatus must be worn. When working on any leak, the buddy system must be used. NEVER WORK ALONE ON LEAKS. When serious leaks occur, the source of the sulfur dioxide should be shut off before attempting to solve the problem.

If the leak is a minor one, the supply valve near the leak can be turned off and the leak repaired. If the leak is near or at the valve, always turn the supply off at the source, such as a cylinder or tank car.

If the leak occurs in the cylinder, the most common shutoff area is at the valve. You can use the chlorine emergency kit that is described in the chlorine sections of this chapter. When the emergency equipment is installed, the container should be returned to the supplier as quickly as possible, provided the supplier is nearby and the container can be returned safely. Otherwise empty the container as quickly as possible.

Ton tank leaks occur mainly at the valves and can be repaired with emergency kits. Leaky tank car valves are the only tank car leaks that can be repaired.

10.823 Employees Authorized to Work on Leaks

All employees that must work around sulfur dioxide should have a regular medical checkup. No one with breathing problems, heart disorders, or similar handicaps should attempt to correct leaks.

In order to be considered qualified, operators must meet the following conditions:

1. Trained in the use of emergency equipment,
2. Good physical and mental health, and
3. Understand that the leak emergency must be stopped by a team consisting of at least two individuals.

10.824 Safety with Sulfur Dioxide

Every good safety program begins with the cooperation of the management and the operator. The operator must take an active part in the safety program and management must support the efforts of the operator. The operator is responsible for taking all necessary steps to prevent accidents. This begins with the proper attitude. All the laws in the world are not enough if both management and operators don't enforce the use of them. OSHA and INDUSTRIAL SAFETY programs were developed for safety reasons. THE BEST SAFETY PROGRAM IS TO STOP ACCIDENTS BEFORE THEY HAPPEN. A safety program should be started and items that should be included are:

1. Establish a safety program
   a. Develop emergency procedures with police and fire departments
   b. List doctors' phone numbers
   c. List fire department's phone number
   d. List ambulance service's phone number
   e. Establish procedure on how to make an emergency phone call
      1) Give the location where accident happened — address
      2) Instruct where the accident took place in the plant and/or where the injured party can be located
2. Prepare written rules to cover the above points
3. Participate in periodic training, including hands-on use of safety equipment
   a. Leak repair equipment
   b. Gas masks
   c. Use and maintenance of detection equipment
4. Conduct a maintenance program for safety equipment

10.825 First Aid

Importance of First Aid

Whenever anyone is overcome by sulfur dioxide, remove the person from the contaminated area and wash the affected parts of the body with large amounts of water. If the clothing is affected, the clothes should be removed and washed thoroughly. If the individual is burned, even slightly, get medical attention from a doctor.

YOU ARE NOT A DOCTOR AND SHOULD NOT APPLY ANY MEDICATION

Keep the individual warm and in a reclining position with head and shoulders slightly elevated. Keep the individual quiet and urge the person to resist coughing if possible.

Asphyxiation

Usually cases of asphyxiation are rare due to the pungent odor of sulfur dioxide. If the individual has stopped breathing, remove the person from the contaminated area and start artificial respiration immediately. Have someone call the fire department, because they are experts and have the necessary equipment to handle this type of emergency. Get the individual to a doctor as soon as possible.

Eyes

If sulfur dioxide gets into the eyes, wash eyes immediately with large amounts of water from an eye wash or running water hose. Keep the eyelids open while washing and wash for at least 15 minutes. Do not give medication. Transport to a doctor as soon as possible.

Skin

If sulfur dioxide gets on the skin, wash off immediately with large amounts of water. Remove any clothing that has been contaminated. If a burn has occurred, transport the injured person to a doctor for treatment and care.

10.826 Emergency Safety Equipment

Gas Masks

All wastewater treatment plants should have a self-contained air breathing apparatus for use with chlorine leaks. These masks are adequate for use during sulfur dioxide leaks.

CANISTER MASKS ARE *NOT* ADEQUATE FOR SEVERE CHLORINE OR SULFUR DIOXIDE LEAKS. THIS TYPE OF EQUIPMENT SHOULD NOT BE NEAR THE PLANT BECAUSE IT MAY LEAD TO SERIOUS ACCIDENTS DUE TO LACK OF OXYGEN OR EXCESSIVE AMOUNTS OF TOXIC GASEOUS CHEMICALS. The recommended type of breathing apparatus is the unit that has its own air or oxygen supply. There are two types of self-contained breathing apparatus. One contains thirty minutes of compressed air and is the same as those used by the fire departments. Pressure-demand units are considered safer than the demand-breathing type. The other uses a canister to manufacture oxygen and is completely self-contained. This device is sometimes called a "rebreather kit."

Container Emergency Kits

The following container emergency kits are available for specified applications.

1. 150-lb Cylinders

   The CHLORINE INSTITUTE EMERGENCY KIT-A contains equipment to stop leaks at the valve, fusible plug, and the tank itself.

2. Ton Tanks

   The CHLORINE INSTITUTE EMERGENCY KIT-B contains equipment to stop leaks at the valve, fusible plug, and tank.

3. Tank Cars and Tank Trucks

   The CHLORINE INSTITUTE EMERGENCY KIT-C contains the equipment to stop leaks only at the valve and the safety valve.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 391.

10.8E What happens when you inhale sulfur dioxide gas?

10.8F How can a sulfur dioxide leak be detected?

KIT A
KIT B
KIT C

10.83 Sulfur Dioxide Supply System

10.830 Sulfur Dioxide Containers

Sulfur dioxide containers and handling facilities are the same as for chlorine. Review Figures 10.7, 10.8, 10.9, 10.10 and 10.11 for pictures and drawings of chlorine containers and handling facilities. Reread Section 10.4, "Chlorine Handling," for a review of the different types of containers and facilities.

There are two important differences between the use of chlorine and sulfur dioxide:

1. Withdrawal rates of sulfure dioxide from containers are slightly lower than the rates for chlorine, and
2. Valves in sulfur dioxide systems should be made of 316 stainless steel with teflon seats.

10.831 Supply Piping

The piping system should be the same as that required for chlorine. Sulfur dioxide usually is not corrosive to most metals when dry. In reality, you don't find completely dry sulfur dioxide gas. There is always some trace of moisture. When sulfur dioxide becomes moist, it is very corrosive, and most metals cannot stand the corrosive action. The best material to use from the source of supply to the sulfonators is Schedule 80 seamless carbon steel pipe with 3000-pound forged steel fittings. Avoid the use of bushings by using reducing fittings instead. All unions should be of the ammonia type with lead gasket joints. Never use ground joint unions.

In some installations, plastic material has been used to connect the sulfonators to the source of supply. Plastic material is, however, ideally suited to carry the sulfur dioxide solution to the point of application.

10.832 Valves

All material used in the valving system should be approved by the Chlorine Institute. There have been problems using bronze bodies and monel stems and seats. Better results have been obtained using 316 stainless steel with teflon seats. Plastic valves such as PVC have been used on solution lines with good results.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 391.

10.8G Why should the piping system carrying sulfur dioxide gas be heated to room temperature?

10.8H How can cylinders be kept from falling over or being knocked down?

10.84 Sulfonation System[41]

10.840 Evaporator

The evaporator is nothing more than a heating system designed to increase the temperature of the liquid sulfur dioxide to the point where it will become a gas.

Liquid sulfur dioxide is piped from the source containers to the sulfur dioxide evaporator. This evaporator is a tank immersed in a constant-temperature hot water bath. The water in the bath is heated to approximately 180°F (82°C). This heat converts the liquid to gas. Liquid sulfur dioxide enters the evaporator at the bottom and sulfur dioxide gas leaves from the top. Due to the construction of the equipment, the gas and liquid are almost at equilibrium.

10.841 Sulfonator

The sulfonator is very similar to a chlorinator, except the orifice and rotameter are different and the diaphragms are manufactured to handle sulfur dioxide rather than chlorine. Actually a sulfonator is a sulfur dioxide gas-metering device. To achieve accuracy with safety while in use, a sulfonator should have:

1. Indicating meter (Rotameter),
2. Sulfur dioxide metering orifice (V-Notch),
3. Manual or automatic feed rate adjuster,
4. Vacuum differential-regulating valve,
5. Pressure-vacuum relief valve, and
6. Injector

The sulfur dioxide feeding system is found in various sizes. These sizes refer to the maximum amount of chemical that can be fed through the control system in lbs per day. The most common of these are:

100 lbs per day	45 kg/day
200	90
250	115
400	180
2000	900
8000	3600

For any size, there are a variety of sizes of rotameters that can be used.

10.842 Injector

The heart of any system is the injector. This injector is merely an aspirator that creates a vacuum in the low pressure area of the barrel. The vacuum is regulated by an orifice opening and the water flowing through the throat of the aspirator. The vacuum of the injector allows the chemical to flow from the storage supply through the sulfonator, the metering device, and into the injector. At the injector, the sulfur dioxide gas is dissolved in water to form sulfurous acid. This will now be referred to as the "sulfur dioxide solution." This solution flows to the point of application.

Injector system design list includes:

1. Injector water-pressure gage,
2. Injector vacuum gage for remote injector installations,
3. Injector vacuum line shut-off valve at the remote injector location,
4. Sulfur dioxide solution pressure gage located immediately downstream of the injector to indicate injector backpressure (this is not required on fixed throat injector systems),
5. Injector water-pressure switch for low water pressure alarm, and
6. Injector water flow meters for multiple sulfonator systems.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 391.

10.8I What is the purpose of the sulfur dioxide evaporator?

10.8J What happens at the injector of a sulfonation system?

10.85 Sulfonator Controls

10.850 Sulfonator Feed-Rate Control

The control of sulfur dioxide flow to point of application in plant effluent is accomplished very much like controlling chlorine flow. Control of the sulfur dioxide feed rate (dosage) to the plant effluent to remove chlorine residual depends on:

1. Chlorine residual, mg/*L*,
2. Plant flow rate, MGD, and
3. Amount (if any) of chlorine to be remaining after addition of sulfur dioxide.

10.851 Control Facilities

Most modern installations do not use manual control of equipment for normal operation. But from time to time, equipment failures occur and make the use of manual controls necessary. Switching from automatic to manual control is usually a matter of turning a set screw or thumb screw to release a spring or some similar mechanism (the procedure depends on the type of sulfonator). Operating under this mode or condition requires the operator to change the dose rate manually every time there is a flow change or a chlorine residual change. This is accomplished by turning the control knob to adjust to the proper dose rate of sulfur dioxide.

To determine the manual setting on a sulfonator, follow the steps outlined in the example calculation. Initially a safety factor of 3.0 mg/*L* of sulfur dioxide more than the chlorine residual is applied. As experience is gained, the 3.0 mg/*L* excess may be gradually reduced to the level actually needed.

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[41] *Evaporators and sulfonators used in sulfonation systems consist of essentially the same equipment as used in chlorination systems. Review Figures 10.13, 10.14 and 10.15 for drawings of chlorination equipment used in sulfonation systems.*

EXAMPLE

A plant with a 2 MGD flow has an effluent residual chlorine of 4.5 mg/*L*. Sulfur dioxide should be applied at 3.0 mg/*L* more than the chlorine residual. Determine the sulfonator feed rate in pounds of sulfur dioxide per day.

Known		**Unknown**
Flow, MGD	= 2 MGD	Sulfonator Feed Rate in pounds SO_2/day
Effl. Cl. Res., mg/*L*	= 4.5 mg/*L*	
SO_2 Dose, mg/*L*	= Cl. Res. + 3.0	

Determine the sulfonator feed rate.

$$\text{Feed Rate, lbs/day} = (\text{Flow, MGD})\ (\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (2\ \text{MGD})(4.5\ \text{mg}/L + 3.0\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 125\ \text{lbs/day or } 57\ \text{kg/day}$$

If plant inflow or chlorine residual changes, repeat calculations and readjust sulfonator feed rate.

Refer to Section 10.20, "Chlorinator Control," for a review of the various types of control facilities.

10.852 Selection of Method of Control

The method used in the operation is usually selected by the design engineer on the basis of a combination of cost and desired effect. A plant that is under strict requirements may use the compound loop system and could also, if funds were short, use a manually paced instrument. The cost must be determined to be reasonable before equipment is selected and installed. If operators are not at the plant 24 hours a day, then one of the automatic control modes should be considered. Even if the operator is present, automatic controls are still the best system.

10.86 Determination of Residual Sulfur Dioxide in Wastewater

Residual sulfur dioxide in plant effluent must be measured to be sure the sulfonator is not overdosing and wasting sulfur dioxide. A residual of 0.5 mg/l or less is satisfactory. Generally, aquatic life can withstand sulfur dioxide concentrations below 20 mg/l; however, this level in an effluent is obviously wasteful. The method for testing residual sulfur dioxide is similar to that for measuring chlorine residual. This technique involves using the amperometric titration procedure. The method used is the back titration approach. The procedure is as follows:

1. Place a 200 ml sample of wastewater in the titrator.
2. Start the agitator.
3. Add 5 ml of 0.00564 *N* phenylarsene oxide (PAO) solution to the sample and mix.
4. Add 4 ml pH 4.0 buffer solution (or enough to attain a pH of between 3.5 and 4.2) to sample and mix.
5. Adjust microammeter pointer so that it reads about 20 on the scale.
6. Add 0.0282N iodine solution in small increments from a 1 ml pipet.
7. The 5 ml of PAO solution will take all of the one ml of iodine solution. Refill the pipet and add the iodine solution in small increments. The end point will be a deflection to the right of the microammeter and will remain to the right.
8. Note the total amount of iodine solution used. This amount should be greater than 1 ml if there is to be any residual sulfur dioxide. The calculation will be:

$$\text{Residual Sulfur Dioxide, mg}/L = (\text{ml iodine solution} - 1.0)(4.5)$$

This calculation assumes a 200 ml sample, 5 ml of 0.00564N PAO solution, and an iodine solution that is 0.0282N.

The excess iodine measures the sulfur dioxide present in the sample. In the absence of an amperometric titrator, starch and a color change from clear to blue may be substituted for the end point.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 391.

10.8K Control of the sulfur dioxide feed rate (dosage) to the plant effluent to remove chlorine residual depends on what factors?

10.8L A treatment plant with a 1.5 MGD flow has an effluent chlorine residual of 3.5 mg/*L*. Apply sulfur dioxide at a dose rate of 3.0 mg/*L* more than the chlorine residual. Determine the sulfonator feed rate in pounds of sulfur dioxide per day.

10.8M Why is the residual sulfur dioxide measured in the plant effluent?

10.87 Operation of Sulfonation Process

10.870 Start-Up of a New System

Before any new system is started, the operators should study the piping system so they know where the shutoff valves are located. A safety program should be discussed, designed, and implemented.

The system should be cleaned, dried, and tested for leaks. Pipelines can be cleaned and dried by flushing with a cleaning solvent, steaming the line with super hot (dry) steam from the high (elevation) side of the system and allowing the condensate and foreign material to drain out. Heat the entire line and blow dry air from one end of the line to the other. Purge line with nitrogen gas. Test the dry air for any moisture by running *DEW POINT TEST*[42] using padding air compressor air supply.

After drying the system for the first time, test the system for leaks. Pressurize the system with air to 150 psi (10.5 kg/sq cm), making sure the air is dry. Maintain the pressure for 24 hours. Some drop in pressure may occur as a result of hot compressor air cooling in the system. If there is a pressure drop due to a leak, inspect for leaks at the joints and valves by using soapy water. After this procedure indicates that the system has passed the test, small amounts of sulfur dioxide may be used. When this is done for the first time, be certain that gas masks are handy. At the first sign of odor, close the supply system. Recheck the system for leaks. Remember: A sulfonator should be used during this check-out; otherwise there will be no place for the sulfur dioxide to go. If a leak develops, the sulfonator should be set at the highest possible feed rate in order to drain (empty) the system of sulfur dioxide so the leak may be repaired.

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[42] *Dew Point Test. Dew point is the temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air. One way to measure the dew point is with a special dew point apparatus. This apparatus consists of a small box. The gas or air being tested enters the box on one side and leaves on the opposite side. One of the other sides has an observation window. A polished cup is inserted firmly in the top.*

Pass a sample of air or gas being tested through the apparatus. Adjust the flow so it can be felt against wetted lips, but not readily felt by the hand. Pour acetone into the cup. Allow the sample to pass through the cup for about five minutes. Add small amounts of crushed dry ice to the acetone. Stir continuously with a thermometer. Carefully add dry ice to the acetone as necessary to slowly lower the temperature. When dew or moisture first appears on the outside polished surface of the cup, read the temperature from the thermometer. This temperature is the DEW POINT. *The lower the dew point, the less moisture in the air. The amount of moisture in the air can be determined from a dew point temperature chart or table provided by manufacturers of dew point measuring equipment.*

10.871 Start-Up of Gas Sulfonators

Start-up procedures for sulfonators using sulfur dioxide gas from containers are outlined in this section.

1. Be sure sulfur dioxide gas valve at the sulfonator is closed. This valve should have been closed already since the sulfonator is out of service.
2. All sulfur dioxide valves on the supply line should have been closed during shutdown. Be sure they are still closed. If any valves are required to be open for any reason, this exception should be indicated by a tag on the valve.
3. Inspect all tubing, manifold and valve connections for potential leaks and be sure all joints are properly gasketed.
4. Check sulfur dioxide solution distribution lines to be sure that system is properly valved to deliver sulfur dioxide solution to desired point of application.
5. Open sulfur dioxide metering orifice slightly by adjusting sulfur dioxide feed-rate control.
6. Start the injector water supply system. Usually the source of water is plant effluent (with a minimum of suspended solids) or potable water (after an air-gap system) supply. The supply water is pumped at an appropriate flow rate and pressure through the injector which creates sufficient vacuum in the injector to draw sulfur dioxide gas. Sulfur dioxide is absorbed and mixed in the water at the injector. The sulfur dioxide solution then is conveyed to the point of application in the plant effluent.
7. Examine injector water supply system.
    a. Note reading of injector supply pressure gage. If reading is abnormal (different from usual reading), try to identify cause and correct.
    b. Note reading of injector vacuum gage. If the vacuum reading is less than normal, the machine may function at a lower feed rate but will be unable to deliver at rated capacity.
8. Inspect sulfonator vacuum lines for leaks.
9. Crack open the sulfur dioxide container valve and allow gas to enter the line. Inspect all joints for leaks by placing an ammonia-soaked rag near each joint. A white cloud will reveal the location of a leak. Start with the valve at the sulfur dioxide container, move down the line and check all joints between this valve and the next one downstream. If the downstream valve passes the ammonia test, open the valve and continue to the next valve. If there are no leaks to the sulfonator, continue with the start-up procedure.
10. Inspect the sulfonator.
    a. Sulfur dioxide gas pressure at the sulfonator should be between 20 and 30 psi (1.4 to 2.1 kg/sq cm).
    b. Operate sulfonator at complete range of feed rates.
    c. Check operation on manual and automatic settings.
11. Sulfonator is ready for use. Log in the time sulfonator was placed into service.

10.872 Troubleshooting the Gas Sulfonator Systems

Operating Symptoms	Probable Cause	Remedy
Injector vacuum reading low	Hydraulic system	Check injector water supply system
	Flow restricted	Adjust injector orifice
	Low pressure	Close throat
	High pressure	Open throat
	Back pressure	Change injector and/or increase water supply to injector
	Low flow of water	Increase pump output
Leaking joints	Missing gasket	Repair joint
Sulfonator will not reach maximum output	Faulty injector (no vacuum)	Repair injector system
	Restriction in supply (no SO_2)	Find restriction in supply system
	Faulty sulfonator	Check for vacuum leaks
	Leaks	Repair leaks
	Wrong orifice	Install proper orifice
Sulfonator will feed OK at maximum output, but will not control at low rates	Vacuum regulating valve	Repair diaphragm
	If equipped with SPRV (Sulfonator Pressure Reducing Valve)	Check valve capsule
		Clean SPRV cartridge, SPRV diaphragm, and SPRV gaskets
Sulfonator does not feed	Supply	Renew SO_2 supply
	Piping	Open valve
		Clean filter
Variable vacuum control, formerly working well, now will not go below 30% feed. Signal OK	SPRV	Clean SPRV
Variable vacuum control reaches full feed, but will not go below 50% feed. SPRV OK	Signal vacuum too high	Hole in diaphragm
		Clean dirty filter disks
		Clean converter nozzle
Variable vacuum control won't go to full feed. Gas pressure OK. SPRV OK	Plugged restrictor	Clean restrictor
	Air leak in signal	Repair air leak
Freezing of manometer	Rate too high	Lower rate
	Restriction in manometer orifice	Clean piping

10.873 Start-Up of Liquid Sulfonators

Start-up procedures for sulfonators using liquid sulfur dioxide from containers are outlined in this section.

1. Inspect all joints, valves, manifolds and tubing connections in sulfonation system, including application lines, for proper fit and for leaks. Make sure that all joints have gaskets.
2. If sulfonation system has been broken open or exposed to the atmosphere, verify that the system is dry. Usually once a system has been dried out, it is never opened again to the atmosphere. However, if moisture enters the system in the air or by any other means, it readily mixes with sulfur dioxide and forms sulfuric acid which will corrode the pipes, valves, joints and fittings.

   To verify that the system is dry, determine the dew point (must be lower than 40°F or 5°C). If not dry, turn the evaporator on, pass dry air through the evaporator and force this air through the system. If this step is omitted and moisture is in the system, serious corrosion damage can result and the entire system may have to be repaired.
3. Start up the evaporators. Fill the water bath and adjust the device according to the manufacturer's directions.
4. Turn on evaporator heaters. Wait until the temperature of the evaporator reaches 180°F (82°C) before proceeding to next step.
5. Inspect and close all valves on the sulfur dioxide supply line.
6. Open the sulfur dioxide metering orifice slightly. This is to prevent damage to the rotameter.
7. Start the injector water supply system.
8. Examine injector water supply system.
   a. Note reading of injector water supply pressure gage. If reading is abnormal (different from usual reading), try to identify cause and correct.
   b. Note reading of injector vacuum gage. If the vacuum reading is less than normal, the machine may function at a lower feed rate, but will be unable to deliver at rated capacity.
9. Inspect sulfonator vacuum lines for leaks.
10. Close all valves on the supply line.
11. Crack open the *GAS LINE* at the sulfur dioxide container. All liquid sulfur dioxide systems should be checked out using gas because of the danger of leaks and also gas is less dangerous. Inspect the joints between this valve and the next one downstream. If this valve passes the ammonia leak test, continue to the next valve down the line. Follow this procedure until the evaporator is reached. Before allowing sulfur dioxide to enter the evaporator and the sulfonator, make sure that all valves between the evaporator and the sulfonator are open. Heat in the evaporator will expand the gas and, if the system is closed, there could be problems. Sulfur dioxide should never be trapped in a line between the evaporator and the sulfonator because heat could expand the gas to the point where pressure levels are dangerous.
12. If no problems develop, the gas line can be put in service by opening the valve 1½ to 2 turns.
13. Check the operation of the sulfonator.
    a. Operate over complete range of sulfur dioxide feed rates.
    b. Check operation on manual and automatic settings.
14. Inspect the liquid sulfur dioxide control valve. If OK, open the liquid sulfur dioxide control valve.
15. After admitting liquid sulfur dioxide to the system, wait until the temperature of the evaporator again reaches 180°F (82°C). Inspect the evaporator.
16. The system is ready for normal operation.

10.874 Troubleshooting the Liquid Sulfonator System

Operating Symptoms	Probable Cause	Remedy
Loss of SO_2 pressure at the sulfonator	Plugged SO_2 filter on supply line	Switch to another sulfonator and clean filter
	SO_2 supply out	Change SO_2 supply
	Supply valve closed	Check valve and system
Liquid through manometer	Rate too high	Lower rate or use another sulfonator
	Reliquefaction	Piping exposed to cold air; heat piping or room
	Water bath temperature off	Adjust temperature setting
	Defective evaporator	Put another evaporator on line. Repair evaporator
Loss of vacuum	Plugged diffuser, high back pressure	Repair diffuser
	Injector	Repair injector
	Loss of water pressure	Check booster pump Check water supply
High vacuum	Supply of SO_2	Check supply Check for closed valves Lower feed rates
Misting	Defective evaporator	Check evaporator Put another evaporator on line
Low temperature alarm on evaporator	Water bath temperature off	Set too low for rate being passed Defective water bath Switch to gas feed from supply

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 392.

10.8N What is the probable cause of joints leaking sulfur dioxide gas?

10.8O Why should sulfur dioxide never be trapped in a line between the evaporator and the sulfonator?

10.875 Normal and Abnormal Operation

The following observations of gages should be checked routinely for proper operation.

Evaporator

1. Water level: Indicates the level of water in the water bath. The level should be in the center of the sight glass.
2. Water temperature: Normal operating range is 180 to 195°F (82 to 91°C).
3. Gas temperature: Normal operating range is 90° to 105°F (32 to 41°C). As impurities are deposited on the evaporator wall, the gas will show a drop in temperature. With experience, the operator should be able to determine when the evaporator needs cleaning.
4. Gas pressure: Should read the same pressure as the supply cylinder or tank.
5. Cathodic protection: The purpose of cathodic protection is to protect the water bath from corrosion damage. The meter should normally read in the 50 to 200 range.

Sulfonator

1. Rotameter: The rotameter indicates the dosage rate of sulfur dioxide and can be set manually or automatically; it should read the same as the established feed rate.
2. Gas pressure: This pressure is normally 20 to 30 psi (1.4 to 2.1 kg/sq cm).
3. Injector suction: Check to see if the unit fluctuates a lot. If it does, the injector water supply should be inspected for the cause.

Procedures and equipment for operating and maintaining chlorination and sulfonation systems are very similar. However, you also should be aware of the differences.

1. Sulfonator control valve diaphragms are made from different material to handle sulfur dioxide, but they may be used for chlorine also. The reverse is not true. Chlorinator control valve diaphragms cannot be used for sulfur dioxide.
2. Chlorinators used as sulfonators cannot deliver the full rated capacity of sulfur dioxide. For example, a chlorinator rated to deliver 2000 pounds (909 kg) of chlorine per day can only deliver approximately 1900 pounds (864 kg) of sulfur dioxide per day. A chlorinator rated at 10,000 pounds (4545 kg) of chlorine per day can deliver only 8,000 pounds (3636 kg) of sulfur dioxide per day.
3. Sulfur dioxide gas pressures from sulfur dioxide containers are lower than chlorine gas pressures at the same temperature. Sulfur dioxide does not vaporize at the same rate as chlorine at the same temperature. Therefore, sulfur dioxide containers are occasionally padded on the gas side with nitrogen to force liquid sulfur dioxide from a container to the evaporator. Consequently reliquefaction sometimes is a problem in the supply lines between the evaporator and the sulfonator.

For additional information on normal and abnormal operation of a sulfonator, see Section 10.26, "Normal and Abnormal Operation of Chlorinators."

10.876 Operational Strategy

For information on the operational strategy for sulfonators, refer to the section on chlorinators, Section 10.28, "Operational Strategy."

10.877 Troubleshooting Sulfonation System

Operating Symptom	Probable Cause	Remedy
Residual chlorine at outfall	Improper mixing	Check for stratification of SO_2
	Broken diffuser	Repair diffuser
	Feed rate too low	Increase feed rate
	Increased plant inflow	Increase SO_2 feed rate
	Chlorine demand increase	Increase SO_2 feed rate or decrease chlorine feed rate if appropriate

10.878 Sulfonation System Shutdown Procedures

Sulfonator system

1. Shut off the sulfur dioxide supply. If the down time is for a brief period, the supply can be shut off at the valve near the sulfonator. If the down time is for a day or more, it is better to shut the supply valve at the source. This allows all the sulfur dioxide to be removed from the system.
2. If the equipment is to be dismantled, wait until the sulfur dioxide supply pressure gage reads zero. Then, remove the flexible connection at the source while still running the equipment. Attach the dry air to this connection. This will insure that all traces of sulfur dioxide are evacuated.
3. After you are sure that all traces of sulfur dioxide are gone, the injector may be turned off. This will secure the installation. The dry air supply also should be turned off at this time.
4. Secure the open end by putting a plug on the flexible connection end. This will prevent moisture from entering the piping.
5. Begin repairs.

Evaporator

If the system is to be shut down for an extended period, it is a good idea to secure the evaporator. In order to do this, drain the evaporator and flush the system with cold water to remove any foreign material. Never leave any sulfur dioxide trapped in the equipment, especially between valves.

10.88 Maintenance of the Sulfur Dioxide Systems

10.880 Supply Area

1. The area should be kept clean and free of unused objects.
2. All lifting devices such as hand trucks and hoists should be properly maintained. A maintenance program should be established.
3. Ventilation system should be periodically inspected for proper operation. Be sure that the fan is running when the switch is in the "ON" position.
4. A record should be kept of all maintenance and repairs.

10.881 Piping

1. Inspect piping periodically, and, if any discoloration appears, the piping should be replaced and tested. Repair any leaks discovered during inspection.
2. All joints should be tested periodically.
3. All fittings, when taken apart, should be checked for wear. Those that are worn must be changed. Proper gaskets should be available for use. Use new gaskets.
4. Whenever joints are opened, they should be plugged immediately. This should be done to prevent moisture from getting into the system and causing serious damage.
5. The flexible connection should be properly stored and dried before each use. Change the flexible connection periodically and throw away the old one.
6. A record should be kept of all maintenance and repairs.

10.882 Evaporator

1. The evaporator should be cleaned every six months. If the supply of sulfur dioxide is dirty, it should be done more frequently.
2. After the evaporator has been cleaned in place for approximately 10 to 12 cleanings, it should be completely taken apart and cleaned. This should be done every five years on a mandatory basis regardless of the cleaning schedule.
3. The manufacturer's cleaning procedure should be followed.
4. New gaskets should be used.
5. A record of maintenance and repairs should be kept. NEVER USE OLD, WORN PARTS.

10.883 Sulfonators

1. Sulfonators should be cleaned every year, or more frequently if necessary.
2. Manufacturer's cleaning procedure should be followed.
3. Never use old, worn parts.
4. A record should be kept of all maintenance and repairs.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 392.

10.8P List the gages that should be checked routinely for proper operation of an evaporator.

10.8Q What are the major differences between sulfonation and chlorination procedures and equipment?

10.8R What areas of the sulfur dioxide system should be included in the maintenance program?

10.9 ARITHMETIC ASSIGNMENT

Turn to the Arithmetic Appendix at the back of this manual and read Sections A.137, Chlorination; A.138, Chemical Doses; and A.139, Blueprint Reading. Check all of the arithmetic in these sections using your electronic pocket calculator. You should be able to get the same answers.

10.10 ADDITIONAL READING

1. *MOP 11*, Chapter 16, "Disinfection," and Chapter 27, "Odor Control."
2. *NEW YORK MANUAL*, Chapter 6, "Disinfection."*
3. *TEXAS MANUAL*, Chapter 21, "Chlorination."
4. *CHLORINE MANUAL*, The Chlorine Institute, Inc., 2001 L Street, Suite 506, Washington, D.C. 20036. Price $10.00.
5. *SAFETY AND HEALTH IN WASTEWATER SYSTEMS*, MOP No. 1, Water Pollution Control Federation, Publications Order Department, 601 Wythe Street, Alexandria, VA 22314-1994. Order #M0001DT. Price to WPCF members, $26.00; others $35.00 plus $4.75 postage and handling.
6. *BASIC GAS CHLORINATION WORKSHOP MANUAL*, Ontario Water Resources Committee (now Ministry of the Environment of Canada). Obtain from Publications Centre, Ministry of Government Services, 880 Bay Street, 5th Floor, Toronto, Ontario M7A 1N8, Canada. Price $6.00, Canadian funds only.
7. *CHLORINE — SAFE HANDLING*, PPG Industries, Inc., Chemicals Group, One PPG Place, Pittsburgh, Pennsylvania 15272.

8. *STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER,* produced by APHA, AWWA, and WPCF, Water Pollution Control Federation, Publications Order Department, 601 Wythe Street, Alexandria, VA 22314-1994. Order #S0026DT. Price $72.00 to members; otherwise $90.00 plus $6.75 postage and handling. Indicate your member association when ordering.

* Depends on edition.

Films on chlorine safety also are available from the Chlorine Institute and PPG Industries, Inc.

10.11 METRIC CALCULATIONS

This section contains the solutions to all problems in this chapter using metric calculations.

10.110 Conversion Factors

lb/day × 0.454 = kg/day

kg/day × 2.205 = lb/day

MGD × 3785 = cu m/day

cu m/day × 0.000264 = MGD

1000 *L* = 1 cu m

10.111 Problem Solutions

1. A chlorinator is set to feed 25 kilograms of chlorine per 24 hours; the wastewater flow is at a rate of 3200 cu m/day, and the chlorine as measured by the chlorine residual test after 30 minutes of contact time is 0.5 mg/*L*. Find the chlorine dosage and chlorine demand in mg/*L*.

Known		**Unknown**
Chlorine Feed, kg/day	= 25 kg/day	1. Chlorine Dose, mg/*L*
Flow, cu m/day	= 3200 cu m/day	2. Chlorine Demand, mg/*L*
Chlorine Residual, mg/*L*	= 0.5 mg/*L*	

1. Calculate the chlorine dose in mg/*L*

$$\text{Chlorine Feed or Dose, mg}/L = \frac{\text{Chlorine Feed, kg/day} \times 1000\ \text{gm/kg} \times 1000\ \text{mg/gm}}{\text{Flow, cu m/day} \times 1000\ L/\text{cu m}}$$

$$= \frac{25\ \text{kg/day} \times 1000\ \text{gm/kg} \times 1000\ \text{mg/gm}}{3200\ \text{cu m/day} \times 1000\ L/\text{cu m}}$$

$$= 7.8\ \text{mg}/L$$

2. Determine the chlorine demand in mg/*L*.

$$\text{Chlorine Demand, mg}/L = \text{Chlorine Dose, mg}/L - \text{Chlorine Residual, mg}/L$$

$$= 7.8\ \text{mg}/L - 0.5\ \text{mg}/L$$

$$= 7.3\ \text{mg}/L$$

2. Calculate the chlorinator setting (kg per 24 hours) to treat a waste with a chlorine demand of 10 mg/*L*, when a chlorine residual of 1 mg/*L* is desired if the flow is 2500 cu m per day.

Known		**Unknown**
Chlorine Demand, mg/*L*	= 10 mg/*L*	Chlorinator Setting, kg/24 hr
Chlorine Residual, mg/*L*	= 1 mg/*L*	
Flow, cu m/day	= 2500 cu m/day	

Calculate the chlorinator setting in kg per 24 hours.

$$\text{Chlorine Dose, mg}/L = \text{Chlorine Demand, mg}/L + \text{Chlorine Residual, mg}/L$$

$$= 10\ \text{mg}/L + 1\ \text{mg}/L$$

$$= 11\ \text{mg}/L$$

$$\text{Chlorinator Setting, kg/day} = \text{Chlorine Dose, mg}/L \times \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \frac{1000\ L}{\text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}$$

$$= 11\ \frac{\text{mg}}{L} \times 2500\ \frac{\text{cu m}}{\text{day}} \times \frac{1000\ L}{\text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}$$

$$= 27.5\ \text{kg/day}$$

$$= 27.5\ \text{kg/24 hours}$$

3. A plant with a flow of 8000 cu m per day has an effluent chlorine residual of 4.5 mg/*L*. Sulfur dioxide should be applied at 3.0 mg/*L* more than the chlorine residual. Determine the sulfonator feed rate in kilograms of sulfur dioxide per day.

Known		**Unknown**
Flow, cu m/day	= 8000 cu m/day	Sulfonator Feed Rate in kilograms SO_2 per day
Effl. Cl. Res., mg/*L*	= 4.5 mg/*L*	
SO_2 Dose, mg/*L*	= Cl. Res. + 3.0	

Determine sulfonator feed rate in kilograms of SO_2 per day.

$$\text{Feed Rate, kg/day} = \text{Flow, } \frac{\text{cu m}}{\text{day}} \times \text{Dose, } \frac{\text{mg}}{L} \times \frac{1000\ L}{1\ \text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}$$

$$= 8000\ \frac{\text{cu m}}{\text{day}} \times \left(4.5\ \frac{\text{mg}}{L} + 3.0\ \frac{\text{mg}}{L}\right) \times \frac{1000\ L}{1\ \text{cu m}} \times \frac{1\ \text{kg}}{1{,}000{,}000\ \text{mg}}$$

$$= 60\ \text{kg/day}$$

END OF LESSON 5 OF 5 LESSONS
ON
DISINFECTION AND CHLORINATION

Please answer the discussion and review questions before continuing.

DISCUSSION AND REVIEW QUESTIONS

Chapter 10. DISINFECTION AND CHLORINATION

(Lesson 5 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 4.

28. Where is the typical application point for sulfur dioxide to dechlorinate a plant effluent?
29. What should you do when you smell or discover a sulfur dioxide leak?
30. Why should flexible connections be used between a railroad tank car containing sulfur dioxide and the unloading structure?
31. What are some of the probable causes of a chlorine residual in the outfall of a plant with a dechlorination system?

SUGGESTED ANSWERS

Chapter 10. DISINFECTION AND CHLORINATION

Answers to questions on page 331.

10.0A The purpose of disinfection is to destroy pathogenic organisms. This is important to prevent the spread of waterborne diseases.

10.0B Pathogenic bacteria are destroyed or removed from water by (1) physical removal through sedimentation or filtration, (2) natural die-away in an unfavorable environment by storage and (3) destruction through chemical treatment.

10.0C Chlorine is used for disinfection because it meets the general requirements of disinfection so well, and because it has been found to be the most economically useful and available chemical for disinfection.

10.0D Sterilization of wastes is impractical and unnecessary and may be detrimental to other treatment processes that are dependent on the activity of nonpathogenic saprophytes.

Answers to questions on page 335.

10.0E Chlorine reacts with organic matter to form chlororganic compounds, and with nitrogenous compounds to form chloramines.

10.0F To produce an effective disinfecting action, sufficient chlorine must be added after the chlorine demand is satisfied to produce a chlorine residual likely to persist through the contact period.

10.0G Chlorine Demand = Chlorine Dose − Chlorine Residual

10.0H Chlorine Dose = Chlorine Demand + Chlorine Residual

10.0I

$$\text{Chlorine Dose, mg}/L = \frac{70 \text{ lb/day}}{(1.2 \text{ MG/day})(8.34 \text{ lb/G})} = 7.0 \frac{\text{lb}}{\text{M lb}}$$

$$= 7.0 \text{ mg}/L$$

$$\text{Chlorine Demand, mg}/L = \text{Chlorine Dose} - \text{Chlorine Residual}$$

$$= 7.0 \text{ mg}/L - 0.4 \text{ mg}/L$$

$$= 6.6 \text{ mg}/L$$

Answers to questions on page 335.

10.0J The objective of disinfection is the destruction of pathogenic bacteria, and the ultimate measure of the effectiveness is the bacteriological result.

10.0K The ultimate measure of effectiveness is the bacteriological result. The residual chlorine that yields satisfactory bacteriological results in a particular plant must be determined and used as a control in that plant.

END OF ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 338.

10.1A The purpose of up-sewer chlorination is to control odors and septicity, prevent deterioration of structures, and decrease BOD load.

10.1B Chlorine should be applied in sewers where odor and H_2S control is necessary. These locations may be at several points in the main intercepting sewer or at the upper ends of feeder lines.

10.1C Prechlorination provides partial disinfection and odor control.

10.1D Plant chlorination provides control of odors, corrosion, sludge bulking, digester foaming, filter ponding, filter flies, or sludge thickening. Be careful that chlorination does not interfere with biological treatment processes.

10.1E Postchlorination is employed primarily for disinfection.

Answers to questions on page 339.

10.2A Chlorine gas feed can be controlled by manual, start-stop, step-rate, timed program, flow proportional, chlorine residual, and compound loop controls.

10.2B Control of chlorine dosage depends on the bacterial *REDUCTION* desired.

10.2C "Amperometric titration" is a means of measuring concentrations of substances in water, such as the chlorine residual.

Answers to questions on page 341.

10.2D Feed in pounds per day can be calculated from the chlorine requirement and the rate of flow by the use of a chlorination control nomogram.

10.2E (1) 4.2 lbs per 24 hrs
(2) 27 lbs per 24 hrs
(3) 1250 lbs per 24 hrs

10.2F Large plants: at least every hour
Medium-sized plants: every 2 to 4 hours
Small plants: every 8 hours

In small plants chlorine costs are relatively low in comparison to labor costs necessary for frequent adjustment.

10.2G Find chlorine dosage in pounds per day.

$$\text{Chlorine Dosage, lbs/day} = \text{Chlorine Dose, mg}/L \times \text{Flow, MGD} \times 8.34\ \text{lbs/gal}$$

$$= 12\ \text{mg}/L \times 0.55\ \text{MGD} \times 8.34\ \text{lbs/gal}$$

$$= 55\ \text{lbs/day}$$

$$\text{HTH Feed Rate, lbs/day} = \frac{\text{Chlorine Required, lbs/day}}{\text{Portion of Chlorine in pounds of HTH}}$$

$$= \frac{55\ \text{lbs/day}}{0.65}$$

$$= 85\ \text{lbs/day}$$

Answers to questions on page 342.

10.2H Little mixing of chlorine solution with wastewater occurs in chlorine contact basins because of the low-flow velocities in a basin.

10.2I Polyvinyl chloride (PVC) or black polyethylene flexible tubing. Rubber-lined steel pipe has been used, but rubber hose is rarely used today.

Answers to questions on page 345.

10.2J Before attempting to start any chlorination system, read the plant Operation and Maintenance Manual and the manufacturer's literature to become familiar with the equipment. Review the plans or drawings of the facility. Determine what equipment, pipelines, pumps, tanks and valves are to be placed into service or are in service. The current status of the entire system must be known before starting or stopping any portion of the system.

10.2K Inspect the chlorination system for leaks by placing an ammonia-soaked rag near each joint and valve. A white cloud or vapor will reveal a chlorine leak.

Answers to questions on page 348.

10.2L Normal operation of a chlorinator includes daily inspection of container storage area, evaporators, and chlorinators, including injectors.

10.2M Evaporators are used to convert liquid chlorine to gaseous chlorine for use by gas chlorinators.

10.2N Abnormal conditions that could be encountered when operating an evaporator include, (1) too low a water level, (2) low water temperatures, and (3) no chlorine gas flow to chlorinator.

10.2O The chlorine residual analyzer can be tested by measuring the chlorine residual and comparing this result with actual residual indicated by analyzer.

10.2P Possible chlorinator abnormal conditions include (1) chlorine leaks, (2) chlorine gas pressure too low, (3) injector vacuum too low, and (4) chlorine residual low.

Answers to questions on page 353.

10.2Q Perform the following steps for the short-term shutdown of a chlorinator:

1. Close chorine-container gas outlet valve,
2. Allow chlorine gas to completely evacuate the system through the injector, and
3. Close chlorinator gas discharge valve.

10.2R Two areas that could hinder an operator's ability to meet NPDES coliform permit requirements when the plant is equipped with standby or backup capabilities are (1) running out of chlorine, and (2) failure of automatic control equipment.

END OF ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 354.

10.3A Chlorine gas is extremely toxic and corrosive in moist atmospheres.

10.3B A properly fitting self-contained air or oxygen supply type of breathing apparatus, pressure demand, or rebreather kits are recommended when repairing a chlorine leak.

10.3C First aid measures depend on the severity of the contact. Remove the victim from the gas area and keep the victim warm and quiet. Call a doctor and fire department immediately. Keep the patient breathing.

Answers to questions on page 362.

10.4A Chlorine may be delivered to a plant in 100- or 150-pound cylinders, ton containers, or tank cars.

10.4B Fusible plugs are provided as a safety device to prevent the building up of excessive pressures and the possibility of rupture due to a fire or high surrounding temperatures.

Answers to questions on page 365.

10.4C To look for a chlorine leak, wear a self-contained breathing apparatus to enter the area if the leak is severe. A rag or paint brush dipped in a strong solution of ammonia water and moved around the area will locate the leak if the room is not full of chlorine gas.

END OF ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 371.

10.5A Chlorine is normally delivered (fed) to the point of application as a solution feed (under-vacuum); however, in some cases it is fed as a direct feed (under pressure).

10.5B Due to the hazards of safely handling sodium chlorite, chlorine dioxide has not been widely used to treat wastewater.

Answers to questions on page 373.

10.5C Chlorinators should be in a separate room because chlorine gas leaks can damage equipment and are hazardous to personnel.

10.5D Room temperature is important for proper chlorinator operation to prevent clogging, chlorine ice formation, and condensation in lines and chlorinator.

10.5E Not more than one pound of chlorine per day per °F (0.8 kg/°C) ambient temperature should be drawn from a chlorine cylinder because of the danger of freezing and slowing up of chlorine flow.

10.5F Adequate ventilation is important in a chlorinator room to remove any leaking chlorine gas.

10.5G Chlorinator rooms can be ventilated using forced ventilation with the outlet near the floor because chlorine is heavier than air.

10.5H Chlorination rates can be checked by use of scales and recorders to measure weight loss.

10.5I Disinfection by chlorination must be continuous for the protection of downstream water users.

10.5J Continuous chlorination can be achieved by the use of a cylinder feed manifold so cylinders can be removed without interrupting feed of gas and also through provision of duplicate units or emergency hypochlorinators.

Answers to questions on page 374.

10.5K The best material for conducting chlorine gas or liquid is seamless carbon steel (Schedule 80).

10.5L Plant effluent is used frequently as the chlorinator injector water supply.

Answers to questions on page 375.

10.6A Hydrogen sulfide odors can be controlled through chlorination by the reaction with sulfide and the delay of decomposition and stabilization. Sulfide should be controlled because it smells like rotten eggs, is a source of corrosion, can paralyze your respiratory tract, and can form explosive mixtures with air.

10.6B Sulfuric acid damage to structures can be minimized by chlorination or oxygenation which destroys hydrogen sulfide. Hydrogen sulfide produces sulfuric acid which damages sewer systems and structures.

END OF ANSWERS TO QUESTIONS IN LESSON 4

Answers to questions on page 377.

10.8A The effluents from some treatment plants are dechlorinated to protect fish and other aquatic organisms from toxic chlorine residuals.

10.8B Dechlorination processes include:

1. Long detention periods,
2. Aeration,
3. Sunlight,
4. Activated carbon, and
5. Chemical reactions, including sulfur dioxide.

10.8C When sulfur dioxide gas comes in contact with moisture, very corrosive sulfuric acid (H_2SO_4) is formed.

10.8D No, sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) will not lower the pH of the effluent significantly because of the small amount of acid produced.

Answers to questions on page 379.

10.8E When you inhale sulfur dioxide gas, sulfurous acid will form on the moist mucous membranes in your body and cause severe irritation or more serious harm. Exposure to high doses of sulfur dioxide can cause death.

10.8F A sulfur dioxide leak can be detected by soaking a cloth with ammonia solution and holding the cloth near suspected areas. A dense white fume will form near the leak. An aspirator or squeeze bottle may be used if the leak is small.

Answers to questions on page 380.

10.8G The piping system carrying sulfur dioxide gas should be heated to room temperature and kept at 80 to 90°F (27 to 32°C) to prevent reliquefaction (gas changing back to liquid again).

10.8H Use a safety chain or clamp to prevent either empty or full cylinders from falling over or being knocked over.

Answers to questions on page 380.

10.8I The purpose of the sulfur dioxide evaporator is to heat liquid sulfur dioxide until it is converted to a gas.

10.8J At the injector, the sulfur dioxide gas is dissolved in water to form sulfurous acid. This sulfur dioxide solution flows to the point of application.

Answers to questions on page 381.

10.8K Control of the sulfur dioxide feed rate (dosage) to the plant effluent to remove chlorine residual depends on:

1. Chlorine residual, mg/*L*,
2. Plant flow rate, MGD, and
3. Amount (if any) of chlorine to be remaining after addition of sulfur dioxide.

10.8L Determine the sulfonator feed rate.

Known		**Unknown**
Flow, MGD	= 1.5 MGD	Sulfonator feed rate in pounds SO_2/day
Effl. Cl. Res., mg/*L*	= 3.5 mg/*L*	
SO_2 Dose, mg/*L*	= Cl. Res., mg/*L* + 3.0 mg/*L*	

Determine the feed rate.

Feed Rate, lbs/day = (Flow, MGD) (Dose, mg/*L*) (8.34 lbs/gal)

= (1.5 MGD) (3.5 mg/*L* + 3.0 m/*L*) (8.34 lbs/gal)

= 82 lbs/day or 37 kg/day

10.8M Residual sulfur dioxide is measured in the plant effluent to be sure the sulfonator is not overdosing and wasting sulfur dioxide.

Answers to questions on page 386.

10.8N The probable cause of joints leaking sulfur dioxide gas is a missing gasket.

10.8O Sulfur dioxide should never be trapped in a line between the evaporator and the sulfonator because heat in the evaporator will expand the gas and the pressure could reach dangerous levels.

Answers to questions on page 387.

10.8P Gages that should be checked routinely for proper operation of an evaporator include (1) water level, (2) gas temperature, (3) water temperature, (4) gas pressure, and (5) cathodic protection.

10.8Q Major differences between sulfonation and chlorination procedures and equipment include (1) sulfonator control valve diaphragms are made of different material than chlorinators, (2) chlorinators used as sulfonators cannot deliver full rated capacity of sulfur dioxide, and (3) sulfur dioxide gas pressures from sulfur dioxide containers are lower than chlorine gas pressures at the same temperature.

10.8R Areas that should be included in the maintenance program for the sulfure dioxide system include (1) supply area, (2) piping, (3) evaporator, and (4) sulfonator.

END OF ANSWERS TO QUESTIONS IN LESSON 5

OBJECTIVE TEST

Chapter 10. DISINFECTION AND CHLORINATION

Please write your name and mark the correct answers on the answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

1. Pathogenic bacteria can cause disease in humans.
   1. True
   2. False
2. Chlorine is an irritant to breathing organs of the body.
   1. True
   2. False
3. Chlorine is only applied at the treatment plant influent (prechlorination) or at the effluent (postchlorination).
   1. True
   2. False
4. When chlorine combines with moisture, the resulting mixture is corrosive.
   1. True
   2. False
5. Leaking chlorine cylinders may be shipped if they are properly tagged.
   1. True
   2. False
6. Effluent from a wastewater treatment plant must be sterilized in order to protect the downstream users of the receiving waters.
   1. True
   2. False
7. Sulfur dioxide smells like chlorine.
   1. True
   2. False
8. You should never tamper with or apply heat to the fusible plug of a chlorine container.
   1. True
   2. False
9. Postchlorination is generally more effective in a well-clarified effluent than in a turbid one.
   1. True
   2. False
10. Hypochlorite compounds are available only in liquid form.
    1. True
    2. False
11. Hydrogen sulfide is found in most collection systems.
    1. True
    2. False
12. Chlorine is toxic.
    1. True
    2. False
13. Postchlorination is used to disinfect the effluent from a wastewater treatment plant.
    1. True
    2. False
14. Knowledge of first aid is required of a competent treatment plant operator.
    1. True
    2. False
15. Never use soapy water to look for a sulfur dioxide leak.
    1. True
    2. False

16. To protect the health of downstream water users, treatment plant effluents must be
    1. Sterilized.
    2. Disinfected.

17. An operator should never enter a room containing high concentrations of chlorine gas without
    1. A self-contained air or oxygen supply.
    2. Help standing by.
    3. Notifying proper authorities.
    4. Protective clothing.

18. Disease-producing bacteria are called
    1. Coliform.
    2. Facultative.
    3. Parasitic.
    4. Pathogenic.
    5. Saprophytes.

19. Reduction in the number of organisms in wastewater may be accomplished by
    1. Adding orthotolidine.
    2. Postchlorination.
    3. Prechlorination.
    4. Providing chlorine contact time.
    5. Sedimentation.

20. Chlorine may be applied for H_2S control in the
    1. Aeration tank.
    2. Collection lines.
    3. Plant effluent.
    4. Plant headworks.
    5. Trickling filter.

21. Chlorine cylinders
    1. Can be handled safely.
    2. Can easily be lifted by one person.
    3. Contain a fusible metal safety plug.
    4. Should be rolled horizontally.
    5. Should be stored at temperatures above 50°F (10°C) and kept away from steam pipes.

22. Chlorine should be applied continuously to
    1. Keep the chlorine pipes from developing leaks.
    2. Keep the chlorine supplier in business.
    3. Keep the plant effluent disinfected.
    4. Keep the plant equipment from breaking down.
    5. Protect the downstream water users.

23. Field chlorination studies have shown that
    1. Actual contact time in most chlorine chambers is the same as the theoretical contact time.
    2. Chlorine feed rates required to produce a desired disinfection level are constant from day to day.
    3. Chlorine residuals can be increased without limit and the coliform densities will always continue to be reduced with each increase in residual.
    4. Constant vigilance is required to maintain a consistently high degree of disinfection at most wastewater treatment plants.
    5. Thorough mixing of chlorine solution with wastewater is essential to achieve maximum efficiency of coliform kill for a given chlorine dosage.

24. Chlorinators should be located
    1. In a room that will not allow chlorine to leak into rooms where operators work or where controls and equipment are located.
    2. In a separate room.
    3. In an adequately heated room.
    4. Near point of application.
    5. Outdoors.

25. Hydrogen sulfide
    1. Can form an explosive mixture with air.
    2. Can paralyze your respiratory system.
    3. Causes odors.
    4. Is associated with corrosion.
    5. Smells like chlorine.

26. Dechlorination of plant effluent may be achieved by
    1. Activated carbon.
    2. Aeration.
    3. Chemical reactions.
    4. Flotation.
    5. Sedimentation.

27. Liquid sulfur dioxide hazards include
    1. An odor like chlorine.
    2. Body tissues freeze when in contact with liquid sulfur dioxide.
    3. Containers can burst if the liquid is excessively heated.
    4. Violent burning on contact with air.
    5. Violent chemical reactions result if water is sucked back into sulfur dioxide in a container.

28. Parts of a sulfonation system include
    1. Evaporator.
    2. Injector.
    3. Respirator.
    4. Rotameter.
    5. Sulfonator.

29. If a sulfonator will not reach maximum output, probable causes include
    1. Chlorine residual too low.
    2. Faulty injector.
    3. Faulty sulfonator.
    4. Restriction in supply line.
    5. Temperature too high in room with sulfur dioxide container.

30. What should be the approximate chlorine feed rate for a flow of 2.0 MGD and a chlorine dosage of 12 mg/*L*?
    1. 200 lbs/24 hr
    2. 100 lbs/24 hr
    3. 24 lbs/24 hr
    4. 12 lbs/24 hr
    5. 2 lbs/24 hr

Review Questions:

A rectangular sedimentation tank 10 feet deep, 30 feet wide, and 120 feet long handles a flow of 3 MGD.

31. The detention time is
    1. 1.5 hr.
    2. 2.0 hr.
    3. 2.15 hr.
    4. 2.25 hr.
    5. 2.5 hr.

32. The surface loading rate is approximately
    1. 500 gpd/sq ft.
    2. 600 gpd/sq ft.
    3. 700 gpd/sq ft.
    4. 800 gpd/sq ft.
    5. 900 gpd/sq ft.

END OF OBJECTIVE TEST
and
END OF VOLUME I

You may work the final exam and correct your own answers if you wish.

CONGRATULATIONS

You've worked hard and completed a very difficult program.

APPENDIX

Final Examination

How to Solve Wastewater Treatment Plant Arithmetic Problems

Glossary

Subject Index

FINAL EXAMINATION

VOLUME I

This final examination was prepared *TO HELP YOU* review the material in Volume I. The questions are divided into four types:

1. True-false,
2. Multiple choice,
3. Problems, and
4. Short answer.

To work this examination:

1. Write the answer to each question in your notebook.
2. After you have worked a group of questions (you decide how many), check your answers with the suggested answers at the end of this exam, and
3. If you missed a question and don't understand why, reread the material in the manual.

You may wish to use this examination for review purposes when preparing for civil service and certification examinations.

Since you have already completed this course, you do not have to send your answers to California State University, Sacramento.

True-False

1. A treatment plant operator may work for an industry.
   1. True
   2. False
2. Every operator has a responsibility to insure that treatment plants are a safe place to work and visit.
   1. True
   2. False
3. Floatable solids are easy to measure.
   1. True
   2. False
4. An industry discharging into municipal collection and treatment systems must have an NPDES permit.
   1. True
   2. False
5. Always wash your hands thoroughly before eating or smoking.
   1. True
   2. False
6. Electrical power must always be shut off before working on equipment.
   1. True
   2. False
7. Barminutors and comminutors are installed for different purposes.
   1. True
   2. False
8. The effluent from primary clarifiers is usually clearer than effluent from secondary clarifiers.
   1. True
   2. False
9. To start a clarifier, fill the tank with water and turn on the sludge collector mechanism.
   1. True
   2. False
10. In a large plant the number of secondary clarifiers on line may change with increases and decreases in seasonal flows or condition of the solids in the secondary system.
    1. True
    2. False
11. Secondary clarifiers allow for liquid-solids separation in secondary biological treatment processes.
    1. True
    2. False
12. Primary clarifier effluent is the same as trickling filter influent in some treatment plants.
    1. True
    2. False
13. Rotating biological contactors treat wastewater by a process similar to the trickling filter process.
    1. True
    2. False
14. Rotating biological contactors usually treat wastewater as a single-stage process.
    1. True
    2. False
15. More food (waste) in the influent to an aeration tank will require a decrease in the oxygen supply to the tank.
    1. True
    2. False

16. Most package plants are of the extended aeration type of activated sludge process.
    1. True
    2. False

17. Oxidation ditches are usually operated in the complete mix mode.
    1. True
    2. False

18. In very cold climates the whole rotor assembly should be left uncovered to reduce ice problems.
    1. True
    2. False

19. Some ponds have been designed to take advantage of percolation and high evaporation rates so that there is no discharge.
    1. True
    2. False

20. A waste treatment pond is a biological process.
    1. True
    2. False

Multiple Choice

1. Organic wastes are in the effluents from which of the following industries?
    1. Dairy
    2. Fruit packing
    3. Gravel washing
    4. Paper
    5. Petroleum

2. Solids are commonly classified as
    1. Inorganic and dissolved.
    2. Inorganic and suspended.
    3. Inorganic and organic.
    4. Organic and dissolved.
    5. Organic and suspended.

3. Hydrogen sulfide gas may
    1. Cause odor problems.
    2. Create a toxic atmosphere.
    3. Damage concrete in plant.
    4. Make wastes more difficult to treat.
    5. Produce an explosive and flammable condition.

4. The purpose of primary sedimentation is to remove
    1. Pathogenic bacteria.
    2. Roots, rags, cans and large debris.
    3. Sand and gravel.
    4. Settleable and floatable materials.
    5. Suspended and dissolved solids.

5. The main operational factors for a barminutor include
    1. Amount of debris in wastewater.
    2. Head loss through the unit.
    3. Location of unit with respect to grit channel.
    4. Number of units in service.
    5. Removal of floatables.

6. When starting or placing a comminutor in service, which of the following items would you perform?
    1. Adjust cutter blades if necessary.
    2. Check appearance and sound of comminutor.
    3. Check for proper positioning of inlet and outlet gates.
    4. Inspect for proper lubrication and oil leaks.
    5. Look for frayed cables.

7. Toxic wastes entering a treatment plant may be detected by observing the
    1. Changes in color of incoming wastewater.
    2. Movements of pointer on the toxic waste recorder.
    3. Recordings of high or low influent pH.
    4. Bulking of sludge in the clarifier.
    5. Smell of odors.

8. Which of the following factors influence the settleability of solids in a clarifier?
    1. Detention time
    2. Flow velocity and/or turbulence
    3. Movement of sludge scrapers
    4. Short-circuiting
    5. Temperature

9. Suspended solids in the effluent from a trickling filter plant may be caused by
    1. Flotation of solids in the primary clarifier.
    2. Heavy sloughing from the filters.
    3. Precipitation of solids in the secondary clarifier.
    4. Shock loading on the trickling filter.
    5. Short-circuiting through the secondary clarifier.

10. When operating a trickling filter, the operator should
    1. Adjust the process to obtain the best possible results for the least cost.
    2. Bubble oxygen up through the filter.
    3. Maintain aerobic conditions in the filter.
    4. Rotate the distributor as fast as possible to better spray settled wastewater over the media.
    5. Use the lowest recirculation rates that will yield good results to conserve power.

11. Which of the following items should be checked before starting a rotating biological contactor process?
    1. Biomass
    2. Clearances
    3. Lubrication
    4. Safety
    5. Tightness

12. What could be the cause of the slime on the media of a rotating biological contactor appearing shaggy with a brown-to-gray color?
    1. BOD overloading
    2. Fluctuating influent flows
    3. High pH values
    4. Proper operation
    5. Toxic substances in influent

13. An operator must be aware of which of the following safety hazards when working around rotating biological contactors?
    1. Infections in cuts or open wounds.
    2. Loose electrical connections and bare wires.
    3. Slippery surfaces caused by water, oil, or grease.
    4. Slow-moving parts or equipment.
    5. Waterborne diseases.

14. How is excess activated sludge wasted and disposed of from package plants?
    1. Aerated in a holding tank and then disposed of in an approved sanitary landfill.
    2. At a nearby treatment plant.
    3. By incineration.
    4. Removal by a septic tank pumper.
    5. Treated by gravity thickening and anaerobic digestion.

15. Maintenance of equipment in package operation plants includes
    1. Adjusting aeration equipment.
    2. Changing oil in speed reducer.
    3. Inspecting air-lift pump.
    4. Regulating scum skimmer.
    5. Washing tank walls and channels.

16. Which of the following factors could cause a demand for more oxygen (increase in aeration rates) in an aeration tank?
    1. Increase in food (BOD) in aeration tank influent.
    2. Increase in inert or inorganic wastes.
    3. Increase in microorganisms.
    4. Increase in pH.
    5. Increase in toxic substances.

17. Pond performance depends on
    1. Lack of short-circuiting.
    2. pH.
    3. Sunlight.
    4. Surface area.
    5. Type and quantity of algae.

18. An increase in plant effluent coliform level could be caused by
    1. Increase in effluent BOD.
    2. Low chlorine residual.
    3. Mixing problems.
    4. Short-circuiting in contact chamber.
    5. Solids accumulation in contact chamber.

19. Low sulfonator injector vacuum reading could be caused by
    1. High back pressure.
    2. Low flow of injector water.
    3. Missing gasket.
    4. Restricted injector flow.
    5. Wrong orifice.

20. Chlorine may be applied for hydrogen sulfide control in the
    1. Aeration tank.
    2. Collection lines.
    3. Plant effluent.
    4. Plant headworks.
    5. Trickling filter.

Short Answer

1. Define the following terms:
   a. Aerobic bacteria
   b. Biochemical oxygen demand
   c. Coliform bacteria
   d. Septic

2. Why should digester gas and air not be allowed to mix?

3. How can explosive conditions develop around bar screens and racks?

4. How can an operator regulate the flow velocity through a grit channel?

5. What is the purpose of a cyclone grit separator?

6. Define alkalinity.

7. List five water quality indicators used to measure clarifier efficiencies.

8. What areas should be studied when reviewing plans and specifications for a treatment plant?

9. What items should be checked daily when operating a trickling filter?

10. How would you attempt to avoid or correct a ponding problem on a trickling filter?

11. Define the following terms:
    a. Grab sample, and
    b. Inhibitory substances.

12. How can the development of biological slimes be encouraged when starting a new rotating biological contactor?

13. How is the activated sludge process controlled?

14. What items should the operator control to maintain the proper environment in an oxidation ditch?

15. List five advantages of ponds.

16. Why are weeds objectionable in and around ponds?

17. Why should the inlet to a pond be submerged?

18. Define the term "air gap."

19. How is the chlorine demand determined?

20. Where is chlorine usually applied for disinfection purposes?

Problems

1. Eight cubic feet of screenings were removed by a plant that treats a flow of 2 MGD during a 24-hour period. How many cubic feet of screenings were removed per MG of flow?

2. Estimate the flow velocity in a grit channel if a stick travels 36 feet in 30 seconds.

3. A circular clarifier with a diameter of 50 feet and a depth of 10 feet treats a flow of 2 MGD. Determine:
   a. Detention time, hours, and
   b. Surface loading, gpd/sq ft.

4. A trickling filter 80 feet in diameter and 4 feet deep treats a flow of 2.4 MGD with a BOD of 120 mg/*L*. Determine:
   a. Hydraulic loading, gpd/sq ft, and
   b. Organic loading, lbs BOD/day/1000 cu ft

5. A rotating biological contactor treats a flow of 2 MGD with a soluble BOD of 80 mg/*L*. The media surface area is 500,000 sq ft. Determine:
   a. Hydraulic loading, gpd/sq ft, and
   b. Organic loading, lbs BOD/day/1000 sq ft.

6. An oxidation ditch has a volume of 20,000 cubic feet. The inflow is 0.2 MGD with a BOD of 200 mg/*L* and suspended solids of 210 mg/*L*. The mixed liquor suspended solids concentration is 3,500 mg/*L* with a volatile matter content of 70 percent. Determine the BOD loading in pounds per day per 1000 cubic feet, F/M ratio, sludge age and detention time.

7. A waste treatment pond treats a flow of 0.1 MGD with a BOD of 180 mg/*L*. The area of the pond is 3 acres. What is the organic loading on the pond?

8. Calculate the setting on a chlorinator (pounds of chlorine per 24 hours) that treats a flow of 2 MGD. The chlorine demand is 9 mg/*L* and the desired residual is 1 mg/*L*.

SUGGESTED ANSWERS FOR FINAL EXAMINATION

VOLUME I

True-False

1. True Treatment plant operators work for industry, sanitation districts and cities.
2. True Everyone has a responsibility to be sure that treatment plants are a safe place to work and visit.
3. False Floatable solids are very difficult to measure.
4. False An industry discharging into municipal collection and treatment systems need not obtain an NPDES permit but must meet certain specified pretreatment standards.
5. True Always wash your hands thoroughly before eating or smoking.
6. True Electrical power must always be shut off before working on equipment.
7. False Barminutors and comminutors are installed for the *SAME* purpose, to shred solids and leave them in wastewater.
8. False The effluent from secondary clarifiers is usually clearer than effluent from primary clarifiers.
9. False To start a clarifier make sure everything is OK, including the collector mechanism, and then fill the tank with water.
10. True In a large plant the number of secondary clarifiers on line should change with changes in flows or the condition of the solids.
11. True Secondary clarifiers allow for liquid-solids separation in secondary biological treatment processes.
12. True Primary clarifier effluent and trickling filter influent can be the same in some plants.
13. True Rotating biological contactors treat wastewater by a process similar to the trickling filter process.
14. False The rotating biological contactor process is usually divided into four stages.
15. False More food (waste) in the influent to an aeration tank will require an increase in the oxygen supply to the tank.
16. True Most package plants are of the extended aeration type of activated sludge process.
17. False Oxidation ditches are usually operated in the extended aeration mode.
18. False The rotor assembly should be covered in very cold climates to reduce ice problems.
19. True Some ponds have been designed so that there is no discharge.
20. True A waste treatment pond is a biological process.

Multiple Choice

1. 1, 2, 4, 5 Gravel washing produces inorganic wastes while the other four industries produce mainly organic wastes.
2. 3 Solids may be classified as either (1) inorganic and organic, or (2) dissolved and suspended.
3. 1, 2, 3, 4, 5 Hydrogen sulfide gas is very dangerous and could cause all of the problems listed.
4. 4 The purpose of primary sedimentation is to remove settleable and floatable materials.
5. 1, 2, 4 Location of unit and removal of floatables are important, but not main operational factors.
6. 1, 2, 3, 4 Comminutors do not have cables, they are found on barminutors.
7. 1, 3, 4, 5 Toxic waste recorders are not available today because of the differences in the many toxic wastes that might enter a plant.
8. 1, 2, 4, 5 Movement of sludge scrapers does not influence settleability of solids.
9. 2, 4, 5 Solids in the effluent from a trickling filter plant may be caused by sloughing, shock loads, and short-circuiting.

10. 1, 3, 5 For good trickling filter operation, maintain aerobic conditions in the filter and adjust the process and recirculation rates to produce good results at the least cost.

11. 2, 3, 4, 5 Check all items but 1, biomass, which won't develop until after the rotating biological contactor has been in operation.

12. 4 Proper operation is the cause of the slime appearing shaggy with a brown-to-gray color.

13. 1, 2, 3, 4, 5 All of the items listed are potential safety hazards around rotating biological contactors.

14. 1, 2, 4 Incineration and gravity thickening usually are not used to treat waste activated sludge from package plants.

15. 1, 3, 4, 5 All items are part of equipment maintenance in a package aeration plant except that speed reducers are used with rotating biological contactors.

16. 1, 3 An increase in food and an increase in microorganisms will cause a demand for more oxygen.

17. 1, 2, 3, 4, 5 Pond performance depends on all five factors.

18. 1, 2, 3, 4, 5 An increase in plant effluent coliform level could be caused by any or all of the five factors listed.

19. 1, 2, 4 Injector vacuum reading low could be caused by high back pressure, low flow or restricted injector flow.

20. 2, 4 Chlorine may be applied for hydrogen sulfide control in the collection lines and plant head works.

Short Answer

1. Define the following terms:
   a. Aerobic bacteria. Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), such as atmospheric oxygen or oxygen dissolved in water.
   b. Biochemical oxygen demand. The rate at which microorganisms use oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions.
   c. Coliform bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination.
   d. Septic. This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

2. Do not allow digester gas and air to mix because this mixture is extremely explosive.

3. Explosive conditions can develop around bar screens and racks because of the possibility of explosive materials and gases from industrial discharges and the accumulation of hydrogen sulfide.

4. Flow velocities in grit channels may be regulated by the number of units in service and by using bricks or cinder blocks to change the cross-sectional shape or area.

5. The purpose of a cyclone grit separator is to separate grit from wastewater and organic material.

6. Alkalinity is the capacity of water or wastewater to neutralize acids.

7. Clarifier efficiencies are measured by the settleable solids, suspended solids, total solids, biochemical oxygen demand and coliform bacteria tests.

8. When reviewing plans and specifications for a treatment plant, carefully study those areas influencing how the plant will be operated and maintained. Also look carefully for potential safety hazards.

9. Items that should be checked daily when operating a trickling filter include:
   1. Any indication of ponding,
   2. Filter flies,
   3. Odors,
   4. Plugged orifices,
   5. Roughness or vibration of the distributor arms, and
   6. Leakage past the seal.

10. Ponding problems on trickling filters may be avoided or corrected by
    1. Maintaining the proper organic and hydraulic loadings,
    2. Being sure the media is of proper size, and
    3. Preventing accumulation of fibers or trash in the filter voids.

11. a. Grab Sample. A single sample of wastewater taken at neither a set time nor flow.
    b. Inhibitory Substances. Materials that kill or restrict the ability of organisms to treat wastes.

12. Development of biological slimes can be encouraged by regulating the flow rate and strength of the wastewater applied to nearly constant levels by the use of recirculation if available. Maintaining building temperatures at 65°F (18°C) or higher will help. The best rotating speed is one which will shear off growth at a rate which will provide a constant "hungry and reproductive" film of microorganisms exposed to the wastewater being treated.

13. Control of the activated sludge process consists of maintaining the proper solids (floc mass) concentration in the aerator for the waste (food) inflow by adjusting the waste sludge pumping rate and regulating the oxygen supply to maintain a satisfactory level of dissolved oxygen in the process.

14. To maintain the proper environment in an oxidation ditch, the operator should
    1. Observe the clearness of the effluent and the color and characteristics of the floc in the ditch,
    2. Control oxidation ditch solids by regulating the return sludge rate and waste sludge rate,
    3. Prevent toxic substances from reaching the ditch, and
    4. Maintain the proper level of dissolved oxygen.

15. Five advantages of ponds include:
    1. Expensive equipment not required.
    2. Highly trained operators not essential.
    3. Economical to construct.
    4. Little energy consumed, and
    5. No sludge handling and disposal problems.

16. Weeds are objectionable in and around ponds because they provide a shelter for the breeding of mosquitoes and scum accumulation and also hinder pond circulation.

17. The inlet to a pond should be submerged to distribute the heat of the influent water as much as possible and to minimize the occurrence of floating material.

18. Air Gap. An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant.

19. Chlorine Demand = Chlorine Dose − Chlorine Residual.

20. Chlorine is usually applied after the other treatment processes for disinfection purposes.

Problems

1. **Known**

Screenings, cu ft = 8 cu ft
Flow, MGD = 2 MGD
Time, hr = 24 hr
or = 1 day

Unknown

Screenings, cu ft/MG

Calculate the screenings removed in cubic feet of screenings per million gallons of flow.

$$\text{Screenings, }\frac{\text{cu ft}}{\text{MG}} = \frac{\text{Screenings, cu ft}}{\text{Flow, MGD} \times \text{Time, day}}$$

$$= \frac{8\text{ cu ft}}{2\text{ MG/day} \times 1\text{ day}}$$

$$= 4\text{ cu ft/MG}$$

2. **Known**

Distance, ft. = 36 ft
Time, sec = 30 sec

Unknown

Velocity, ft/sec

Estimate the flow velocity in the grit channel.

$$\text{Velocity, ft/sec} = \frac{\text{Distance Traveled, ft}}{\text{Time, sec}}$$

$$= \frac{36\text{ ft}}{30\text{ sec}}$$

$$= 1.2\text{ ft/sec}$$

3. **Known**

Diameter, ft = 50 ft
Depth, ft = 10 ft
Flow, MGD = 2 MGD

Unknown

a. Detention time, hrs
b. Surface loading, gpd/sq ft

a. Estimate the detention time in hours.

$$\text{Detention Time, hrs} = \frac{\text{Tank Vol, cu ft} \times 7.5\text{ gal/cu ft} \times 24\text{ hr/day}}{\text{Flow, gal/day}}$$

$$= \frac{(\pi/4)(50\text{ ft})^2\,(10\text{ ft}) \times 7.5\text{ gal/cu ft} \times 24\text{ hr/day}}{2{,}000{,}000\text{ gal/day}}$$

$$= 1.8\text{ hours}$$

b. Calculate the surface loading in gallons per day per surface square foot.

$$\text{Surface Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Area, sq ft}}$$

$$= \frac{2{,}000{,}000\text{ gpd}}{(\pi/4)(50\text{ ft})^2}$$

$$= 1{,}020\text{ gpd/sq ft}$$

4. **Known**

Diameter, ft = 80 ft
Depth, ft = 4 ft
Flow, MGD = 2.4 MGD
BOD, mg/*L* = 120 mg/*L*

Unknown

a. Hydraulic Loading, gpd/sq ft
b. Organic Loading, lbs BOD/day/100 cu ft

a. Calculate the hydraulic loading in gallons per day per square foot of filter surface area.

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{2{,}400{,}000\text{ gpd}}{(\pi/4)(80\text{ ft})^2}$$

$$= \frac{2{,}400{,}000\text{ gpd}}{5{,}027\text{ sq ft}}$$

$$= 477\text{ gpd/sq ft}$$

b. Estimate the organic loading in pounds of BOD per day per 1,000 cubic feet of media.

$$\frac{\text{Organic Loading, lbs BOD/day}}{1000\text{ cu ft}} = \frac{\text{BOD, lbs/day}}{\text{Volume of Media (in 1000 cu ft)}}$$

$$= \frac{(\text{Flow, MGD})\,(\text{BOD, mg}/L)\,(8.34\text{ lbs/gal})}{(\pi/4)\,(\text{Diameter, ft})^2\,(\text{Depth, ft})}$$

$$= \frac{(2.4\text{ MGD})\,(120\text{ mg}/L)\,(8.34\text{ lbs/gal})}{(\pi/4)\,(80\text{ ft})^2\,(4\text{ ft})}$$

$$= \frac{2402\text{ lbs BOD/day}}{20{,}106\text{ cu ft}}$$

$$= \frac{2402\text{ lbs BOD/day}}{20.106\text{ (1000 cu ft)}}$$

$$= 120\text{ lbs BOD/day/1000 cu ft}$$

5. **Known**

Flow, MGD = 2 MGD
Soluble BOD, mg/*L* = 80 mg/*L*
Surface Area, sq ft = 500,000 sq ft

Unknown

a. Hydraulic Loading, gpd/sq ft
b. Organic Loading, lbs BOD/day/1000 sq ft

a. Calculate the hydraulic loading in gallons per day per square foot of media surface area.

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{2{,}000{,}000\text{ gpd}}{500{,}000\text{ sq ft}}$$

$$= 4\text{ gpd/sq ft}$$

b. Estimate the organic loading in pounds of BOD per day per 1,000 square feet of media surface area.

$$\frac{\text{Organic Loading, lbs BOD/day}}{\text{1,000 sq ft}} = \frac{\text{BOD, lbs/day}}{\text{Surface Area (in 1000 sq ft)}}$$

$$= \frac{\text{(Flow, MGD) (BOD, mg/}L\text{) (8.34 lbs/gal)}}{\text{Surface Area (in 1000 sq ft)}}$$

$$= \frac{\text{(2 MGD) (80 mg/}L\text{) (8.34 lbs/gal)}}{\text{500 (1000 sq ft)}}$$

$$= \text{2.7 lbs BOD/day/1000 sq ft}$$

6.

Known			Unknown
Ditch Volume, cu ft	= 20,000 cu ft	a.	BOD Loading, lbs/day/1000 cu ft
or	= 0.15 MG		
Flow, MGD	= 0.2 MGD	b.	F/M Ratio
BOD, mg/*L*	= 200 mg/*L*	c.	Sludge Age, days
SS, mg/*L*	= 210 mg/*L*	d.	Detention Time, hrs
MLSS, mg/*L*	= 3500 mg/*L*		
VM, %	= 70%		

a. Calculate the BOD loading in pounds of BOD per day per 1000 cubic feet of ditch.

$$\frac{\text{BOD Loading, lbs BOD/day}}{\text{1000 cu ft}} = \frac{\text{BOD, lbs/day}}{\text{Ditch Volume, 1000 cu ft}}$$

$$= \frac{\text{(Flow, MGD) (BOD, mg/}L\text{) (8.34 lbs/gal)}}{\text{Volume (in 1000 cu ft)}}$$

$$= \frac{\text{(0.2 MGD) (200 mg/}L\text{) (8.34 lbs/gal)}}{\text{20,000 cu ft}}$$

$$= \frac{\text{333.6 lbs BOD/day}}{\text{20.0 (1000 cu ft)}}$$

$$= \text{16.7 lbs BOD/day/1000 cu ft}$$

b. Determine the Food/Microorganism Ratio.

$$\frac{F}{M} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{(Flow, MGD) (BOD, mg/}L\text{) (8.34 lbs/gal)}}{\text{(Vol., MG) (MLSS, mg/}L\text{) (VM) (8.34 lbs/gal)}}$$

$$= \frac{\text{(0.2 MGD) (200 mg/}L\text{) (8.34 lbs/gal)}}{\text{(0.15 MG) (3500 mg/}L\text{) (0.70) (8.34 lbs/gal)}}$$

$$= \frac{\text{333.6 lbs BOD/day}}{\text{3065 lbs MLVSS}}$$

$$= \text{0.11 lbs BOD/day/lb MLVSS}$$

c. Estimate the sludge age in days.

$$\text{Sludge Age, days} = \frac{\text{Solids Under Aeration, lbs}}{\text{Solids Added, lbs/day}}$$

$$= \frac{\text{(Vol., MG) (MLSS, mg/}L\text{) (8.34 lbs/gal)}}{\text{(Flow, MGD) (Infl. SS, mg/}L\text{) (8.34 lbs/gal)}}$$

$$= \frac{\text{(0.15 MG) (3500 mg/}L\text{) (8.34 lbs/gal)}}{\text{(0.2 MGD) (210 mg/}L\text{) (8.34 lbs/gal)}}$$

$$= \frac{\text{4379 lbs}}{\text{350 lbs/day}}$$

$$= \text{12.5 days}$$

d. Calculate the detention time in hours.

$$\text{Detention Time, hours} = \frac{\text{(Ditch Volume, MG) (24 hr/day)}}{\text{Flow, MGD}}$$

$$= \frac{\text{(0.15 MG) (24 hr/day)}}{\text{0.2 MGD}}$$

$$= \text{18 hours}$$

7.

Known		Unknown
Flow, MGD	= 0.1 MGD	Organic Loading, lbs BOD/day/ac
BOD, mg/*L*	= 180 mg/*L*	
Area, acres	= 3 acres	

Calculate the organic (BOD) loading on the pond in pounds per day per acre.

$$\text{Organic Loading, lbs BOD/day/ac} = \frac{\text{(Flow, MGD) (BOD, mg/}L\text{), (8.34 lbs/gal)}}{\text{Area, acres}}$$

$$= \frac{\text{(0.1 MGD) (180 mg/}L\text{) (8.34 lbs/gal)}}{\text{3 acres}}$$

$$= \frac{\text{150 lbs BOD/day}}{\text{3 acres}}$$

$$= \text{50 lbs BOD/day/ac}$$

8.

Known		Unknown
Flow, MGD	= 2 MGD	Chlorinator Setting, lbs/24 hours
Cl Demand, mg/*L*	= 9 mg/*L*	
Cl Residual, mg/*L*	= 1 mg/*L*	

a. Estimate the chlorine dose in mg/*L*.

Cl Dose, mg/*L* = Cl Demand, mg/*L* + Cl Residual, mg/*L*

= 9 mg/*L* + 1 mg/*L*

= 10 mg/*L*

b. Calculate the chlorinator setting in pounds of chlorine per 24 hours.

Setting, lbs/24 hr = (Flow, MGD) (Dose, mg/*L*) (8.34 lbs/gal)

= (2 MGD) (10 mg/*L*) (8.34 lbs/gal)

= 167 lbs/day

or = 170 lbs/24 hours

APPENDIX

HOW TO SOLVE WASTEWATER TREATMENT PLANT ARITHMETIC PROBLEMS

TABLE OF CONTENTS

HOW TO SOLVE WASTEWATER TREATMENT PLANT ARITHMETIC PROBLEMS

Page

OBJECTIVES 410

A.0 How to Study This Appendix 410

A.1 Basic Arithmetic 410

- A.10 Addition 410
- A.11 Subtraction 410
- A.12 Multiplication 410
- A.13 Division 411
- A.14 Multiplication and Division 411
- A.15 Actual Problems 411
- A.16 Percentage 412
- A.17 Sample Problems Involving Percent 412

A.2 Areas 413

- A.20 Units 413
- A.21 Rectangle 413
- A.22 Triangle 413
- A.23 Circle 414
- A.24 Cylinder 414
- A.25 Cone 415
- A.26 Sphere 415

A.3 Volumes 415

- A.30 Rectangle 415
- A.31 Prism 416
- A.32 Cylinder 416
- A.33 Cone 416
- A.34 Sphere 416

A.4 Metric System 416

- A.40 Measures of Length 417
- A.41 Measures of Capacity or Volume 417
- A.42 Measures of Weight 417
- A.43 Temperature 417
- A.44 Milligrams per Liter 418
- A.45 Example Problems 418

Page

A.5 Weight-Volume Relations 419
A.6 Force, Pressure, and Head 419
A.7 Velocity and Flow Rate 420
    A.70 Velocity 420
    A.71 Flow Rate 420
A.8 Pumps 421
    A.80 Pressure 421
    A.81 Work 421
    A.82 Power 421
    A.83 Horsepower 422
    A.84 Head 422
    A.85 Pump Characteristics 423
    A.86 Evaluation of Pump Performance 424
    A.87 Pump Speed — Performance Relationships 425
    A.88 Friction or Energy Losses 425
A.9 Steps in Solving Problems 428
    A.90 Identification of Problem 428
    A.91 Selection of Formula 428
    A.92 Arrangement of Formula 428
    A.93 Unit Conversions 429
    A.94 Calculations 429
    A.95 Significant Figures 429
    A.96 Check Your Results 430
A.10 Basic Conversion Factors (English System) 430
A.11 Basic Formulas 430
A.12 How to Use the Basic Formulas 431
A.13 Typical Wastewater Treatment Plant Problems (English System) 432
    A.130 Flows 432
    A.131 Grit Channels 432
    A.132 Sedimentation Tanks and Clarifiers 432
    A.133 Trickling Filters 433
    A.134 Rotating Biological Contactors 434
    A.135 Activated Sludge 434
    A.136 Ponds 435
    A.137 Chlorination 435
    A.138 Chemical Doses 435
    A.139 Blueprint Reading 437

Page

A.14 Basic Conversion Factors (Metric System) 439

A.15 Typical Wastewater Treatment Plant Problems (Metric System) 439

- A.150 Flows 439
- A.151 Grit Channels 439
- A.152 Sedimentation Tanks and Clarifiers 439
- A.153 Trickling Filters 440
- A.154 Rotating Biological Contactors 441
- A.155 Activated Sludge 441
- A.156 Ponds 442
- A.157 Chlorination 442
- A.158 Chemical Doses 442
- A.159 Blueprint Reading 444

OBJECTIVES

HOW TO SOLVE WASTEWATER TREATMENT PLANT ARITHMETIC PROBLEMS

After completion of this Appendix, you should be able to do the following:

1. Add, subtract, multiply and divide.
2. List from memory basic conversion factors and formulas, and
3. Solve wastewater treatment plant arithmetic problems.

APPENDIX. HOW TO SOLVE WASTEWATER TREATMENT PLANT ARITHMETIC PROBLEMS

A.0 HOW TO STUDY THIS APPENDIX

This appendix may be worked early in your training program to help you gain the greatest benefit from your efforts. Whether to start this appendix early or wait until later is your decision. The chapters in this manual were written in a manner requiring very little background in arithmetic. You may wish to concentrate your efforts on the chapters and refer to this appendix when you need help. Some operators prefer to complete this appendix early so they will not have to worry about how to do the arithmetic when they are studying the chapters. You may try to work this appendix early or refer to it while studying the other chapters.

The intent of this appendix is to provide you with a quick review of the addition, subtraction, multiplication and division needed to work the arithmetic problems in this manual. This appendix is not intended to be a math textbook. There are no fractions because you don't need fractions to work the problems in this manual. Some operators will be able to skip over the review of addition, subtraction, multiplication and division. Others may need more help in these areas. If you need help in solving problems, read Section A.9, "Steps in Solving Problems." Basic arithmetic textbooks are available at every local library or bookstore and should be referred to if needed. Most instructional or operating manuals for pocket electronic calculators contain sufficient information on how to add, subtract, multiply, and divide.

After you have worked a problem involving your job, you should check your calculations, examine your answer to see if it appears reasonable, and if possible have another operator check your work before making any decisions or changes.

A.1 BASIC ARITHMETIC

In this Section we are going to provide you with basic arithmetic problems involving addition, subtraction, multiplication and division. You may work the problems "by hand" if you wish, but we recommend you use an electronic pocket calculator. The operating or instructional manual for your calculator should outline the step-by-step procedures to follow. All calculators use similar procedures, but most of them are slightly different from others.

We will start with very basic, simple problems. Try working the problems and then comparing your answers with the given answers. If you can work these problems, you should be able to work the more difficult problems in the text of this training manual by using the same procedures.

A.10 Addition

2 3	6.2 8.5	16.7 38.9	6.12 38.39	43 39 34 38 39 37 29
5	14.	55.6	44.51	259
2.12 9.80	0.12 2.0	63 32	120 60	
11.92	2.12	95	180	
4 7 2	23 79 31	16.2 43.5 67.8	45.98 28.09 114.00	70 50 40 80
13	133	127.5	188.07	240

A.11 Subtraction

7 −5	12 − 3	25 − 5	78 −30	83 −69
2	9	20	48	14
61 −37	485 −296	4.3 −0.8	3.5 −0.7	123 −109
24	189	3.5	2.8	− 14
8.6 −8.22	11.92 − 3.70	27.32 −12.96	3.574 −0.042	75.132 −49.876
0.38	8.22	14.36	3.532	25.256

A.12 Multiplication

(3)(2)[a] = 6 (4)(7) = 28

(10)(5) = 50 (10)(1.3) = 13

(2)(22.99) = 45.98 (6)(19.5) = 117

(16)(17.1) = 273.6 (50)(20,000) = 1,000,000

(40)(2.31) = 92.4 (80)(0.433) = 34.6

(40)(20)(6) = 4,800

(4,800)(7.48) = 35,904

(1.6)(2.3)(8.34) = 30.6912

(0.001)(200)(8.34) = 1.668

(0.785)(7.48)(60) = 352.308

(12,000)(500)(60)(24) = 8,640,000,000 or 8.64×10^9

(4)(1000)(1000)(454) = 1,816,000,000 or 1.816×10^9

NOTE: The term, $\times 10^9$, means that the number is multiplied by 10^9 or 1,000,000,000. Therefore 8.64×10^9 = $8.64 \times 1{,}000{,}000{,}000$ = 8,640,000,000.

---

[a] (3)(2) is the same as 3 × 2 = 6.

A.13 Division

$$\frac{6}{3} = 2 \qquad \frac{48}{12} = 4$$

$$\frac{50}{25} = 2 \qquad \frac{300}{20} = 15$$

$$\frac{20}{7.1} = 2.8 \qquad \frac{11{,}400}{188} = 60.6$$

$$\frac{1{,}000{,}000}{17.5} = 57{,}143 \qquad \frac{861{,}429}{30{,}000} = 28.7$$

$$\frac{4{,}000{,}000}{74{,}880} = 53.4 \qquad \frac{1.67}{8.34} = 0.20$$

$$\frac{80}{2.31} = 34.6 \qquad \frac{62}{454} = 0.137$$

$$\frac{250}{17.1} = 14.6 \qquad \frac{4{,}000{,}000}{14.6} = 273{,}973$$

NOTE: When we divide ⅓ = 0.3333, we get a long row of 3s. Instead of the row of 3s, we "round-off" our answer so ⅓ = 0.33. For a discussion of rounding off numbers, see Section A.95, "Significant Figures."

A.14 Multiplication and Division

Many of the problems we work in the wastewater field involve both multiplication and division. Sometimes addition or subtraction is also involved. To work these types of problems:

1. Do all the addition and subtraction above and below the line,
2. Do all the multiplication above and below the line, and
3. Perform the division.

Instructions for your electronic calculator can provide you with the detailed procedures.

$$\frac{(3)(4)}{2} = 6 \qquad \frac{64}{(8)(4)} = 2$$

$$\frac{(2+3)(4)}{5} = 4 \qquad \frac{(54)}{(4+2)(3)} = 3$$

$$\frac{(7-2)(8)}{4} = 10 \qquad \frac{48}{(8-3)(4)} = 2.4$$

$$\frac{(9)(8)-(6)(6)}{3} = 12 \qquad \frac{(16)(6)}{(8)(7)-(4)(4)} = 2.4$$

$$\frac{(20)}{(0.85)(8.34)} = 2.82 \qquad \frac{30-27}{(1.6)(8.34)} = 0.22$$

$$\frac{(14)(2)}{(13.53-12.98)(8.34)} = 6.10$$

$$\frac{(13)(100)}{(120)(8.34)} = 1.3$$

$$\frac{861{,}429}{(500)(60)} = 28.7$$

$$\frac{(4)(1{,}000{,}000)}{74{,}880} = 53.4$$

$$\frac{(15{,}000)(7.48)(24)}{(1.4)(1{,}000{,}000)} = 1.9$$

$$\frac{(225-25)(100)}{225} = 88.9$$

$$\frac{12}{(0.432)(8.34)} = 3.3$$

$$\frac{(1800)(0.5)(8.34)}{(110)(2.0)(8.34)} = 4.1$$

A.15 Actual Problems

Let's look at the last four problems in the previous Section A.14, "Multiplication and Division," as they might be encountered by an operator.

1. A rectangular sedimentation basin treats a flow of 1.4 MGD. The volume is 15,000 cubic feet. Estimate the detention time.

Known		Unknown
Basin Volume, cu ft	= 15,000 cu ft	Detention Time, hours
Flow, MGD	= 1.4 MGD	

Calculate the detention time in hours.

$$\text{Detention Time, hrs} = \frac{(\text{Basin Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{(\text{Flow, MGD})(1{,}000{,}000/\text{M})}$$

$$= \frac{(15{,}000\ \text{cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{(1.4\ \text{MGD})(1{,}000{,}000/\text{M})}$$

$$= \frac{(15{,}000)(7.48)(24)}{(1.4)(1{,}000{,}000)}$$

$$= 1.9\ \text{hours}$$

2. The influent BOD to an activated sludge plant is 225 mg/*L* and the effluent BOD is 25 mg/*L*. What is the BOD removal efficiency of the plant?

Known		Unknown
Influent BOD, mg/*L*	= 225 mg/*L*	Plant Efficiency, %
Effluent BOD, mg/*L*	= 25 mg/*L*	

Calculate the efficiency of the plant in removing BOD.

$$\text{Plant BOD Efficiency, \%} = \left(\frac{\text{In-Out}}{\text{In}}\right)(100\%)$$

$$= \left(\frac{225\ \text{mg}/L - 25\ \text{mg}/L}{225\ \text{mg}/L}\right)(100\%)$$

$$= \left(\frac{225-25}{225}\right)(100\%)$$

$$= 88.9\%$$

3. A chlorinator is set to feed twelve pounds of chlorine per day to a flow of 300 gallons per minute (0.432 million gallons per day). What is the chlorine dose in milligrams per liter?

Known		Unknown
Chlorinator Feed, lbs/day	= 12 lbs/day	Chlorine Dose, mg/*L*
Flow, MGD	= 0.432 MGD	

Determine the chlorine dose in milligrams per liter.

$$\begin{aligned}\text{Chlorine Dose, mg}/L &= \frac{\text{Chlorinator Feed Rate, lbs/day}}{(\text{Flow, MGD})(8.34\text{ lbs/gal})}\\ &= \frac{12\text{ lbs/day}}{(0.432\text{ MGD})(8.34\text{ lbs/gal})}\\ &= \frac{12}{(0.432)(8.34)}\\ &= 3.3\text{ mg}/L\end{aligned}$$

4. Estimate the sludge age for an activated sludge plant with a mixed liquor suspended solids (MLSS) of 1800 mg/*L* and an aeration tank volume of 0.50 MG. The flow is 2.0 MGD and primary effluent suspended solids are 110 mg/*L*.

Known	**Unknown**
MLSS, mg/*L* = 1800 mg/*L*	Sludge Age, days
P.E. SS, mg/*L* = 110 mg/*L*	
Tank Vol, MG = 0.50 MG	
Flow, MGD = 2.0 MGD	

Calculate the sludge age for the aeration tank in days.

$$\begin{aligned}\text{Sludge Age, days} &= \frac{(\text{MLSS, mg}/L)(\text{Tank Vol, MG})(8.34\text{ lbs/gal})}{(\text{P.E. SS, mg}/L)(\text{Flow, MGD})(8.34\text{ lbs/gal})}\\ &= \frac{(1800\text{ mg}/L)(0.50\text{ MG})(8.34\text{ lbs/gal})}{(110\text{ mg}/L)(2.0\text{ MGD})(8.34\text{ lbs/gal})}\\ &= \frac{(1800)(0.50)(8.34)}{(110)(2.0)(8.34)}\\ &= 4.1\text{ days}\end{aligned}$$

A.16 Percentage

Expressing a number in percentage is just another, and sometimes simpler, way of writing a fraction or a decimal. It can be thought of as parts per 100 parts, since the percentage is the numerator of a fraction whose denominator is always 100. Twenty-five parts per 100 parts is more easily recognized as 25/100 or 0.25. However, it is also 25%. In this case, the symbol % takes the place of the 100 in the fraction and the decimal point in the decimal fraction.

For the above example it can be seen that changing from a fraction or a decimal to percent is not a difficult procedure.

1. To change a fraction to percent, multiply by 100%.

   Example: $\frac{2}{5} \times 100\% = \frac{200\%}{5} = 40\%$

   Example: $\frac{5}{4} \times 100\% = \frac{500\%}{4} = 125\%$

2. To change percent to a fraction, divide by 100%.

   Example: $15\% \div 100\% = 15\% \times \frac{1}{100\%} = \frac{15}{100} = \frac{3}{20}$

   Example: $0.4\% \div 100\% = 0.4\% \times \frac{1}{100\%} = \frac{.4}{100} = \frac{4}{1000} = \frac{1}{250}$

   In these examples note that the two percent signs cancel each other.

Following is a table comparing common fractions, decimal fractions, and percent to indicate their relationship to each other:

Common Fraction	Decimal Fraction	Percent
$\frac{285}{100}$	2.85	285%
$\frac{100}{100}$	1.0	100%
$\frac{20}{100}$	0.20	20%
$\frac{1}{100}$	0.01	1%
$\frac{1}{1000}$	0.001	0.1%
$\frac{1}{1{,}000{,}000}$	0.000001	0.0001%

A.17 Sample Problems Involving Percent

Problems involving percent are usually not complicated since their solution consists of only one or two steps. The principal error made is usually a misplaced decimal point. The most common type percentage problem is finding:

1. *WHAT PERCENT ONE NUMBER IS OF ANOTHER*

   In this case, the problem is simply one of reading carefully to determine the correct fraction and then converting to a percentage.

   Example: What percent is 20 of 25?

   $$\frac{20}{25} = \frac{4}{5} = 0.8$$

   $$0.8 \times 100\% = 80\%$$

   Example: Four is what percent of 14?

   $$\frac{4}{14} = 0.2857$$

   $$0.2857 \times 100\% = 28.57\%$$

   Example: Influent BOD to a clarifier is 200 mg/*L*. Effluent BOD is 140 mg/*L*. What is the percent removal in the clarifier?

   $$\begin{aligned}\text{Removal, \%} &= \left(\frac{\text{In-Out}}{\text{In}}\right) \times 100\%\\ &= \left(\frac{200\text{ mg}/L - 140\text{ mg}/L}{200\text{ mg}/L}\right) \times 100\%\\ &= 30\%\end{aligned}$$

2. *PERCENT OF A GIVEN NUMBER*

   In this case the percent is expressed as a decimal, and the two numbers are multiplied together.

   Example: Find 7% of 32.

   $$\frac{7\%}{100\%} \times 32 = 2.24$$

   Example: Find 90% of 5.

   $$\frac{90\%}{100\%} \times 5 = 4.5$$

   Example: What is the weight of dry solids in a ton (2000 lbs) of wastewater sludge containing 5% solids and 95% water?

NOTE: 5% solids means there are 5 lbs of dry solids for every 100 lbs of wet sludge.

Therefore

$$2000 \text{ lbs} \times \frac{5\%}{100\%} = 100 \text{ lbs of solids}$$

A variation of the preceding problem is:

3. *FINDING A NUMBER WHEN A GIVEN PERCENT OF IT IS KNOWN*

Since this problem is similar to the previous problem, the solution is to convert to a decimal and divide by the decimal.

Example: If 5% of a number is 52, what is the number?

$$\left(\frac{100\%}{5\%}\right)(52) = 1040$$

A check calculation may now be performed — what is 5% of 1040?

$$\left(\frac{5\%}{100\%}\right)(1040) = 52 \text{ (Check)}$$

Example: 16 is 80% of what amount?

$$\left(\frac{100\%}{80\%}\right)(16) = 20$$

Example: Percent removal of BOD in a clarifier is 35%. If 70 mg/*L* are removed, what is the influent BOD?

$$\text{Influent BOD} = \left(\frac{70}{35\%}\right)(100\%) = 200 \text{ mg}/L$$

Check:

Original load × % removal = load removed

$$200 \text{ mg}/L \times \frac{35\%}{100\%} = 70 \text{ mg}/L$$

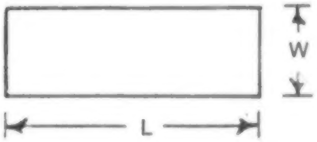
A.2 AREAS

A.20 Units

Areas are measured in two dimensions or in square units. In the English system of measurement the most common units are square inches, square feet, square yards, and square miles. In the metric system the units are square millimeters, square centimeters, square meters, and square kilometers.

A.21 Rectangle

The area of a rectangle is equal to its length (L) multiplied by its width (W).



A = L × W

Example: Find the area of a rectangle if the length is 5 feet and the width is 3.5 feet.

$$\begin{aligned} \text{Area, sq ft} &= \text{Length, ft} \times \text{Width, ft} \\ &= 5 \text{ ft} \times 3.5 \text{ ft} \\ &= 17.5 \text{ ft}^2 \\ &= 17.5 \text{ sq ft} \end{aligned}$$

Example: The surface area of a sedimentation basin is 330 square feet. One side measures 15 feet. How long is the other side?

$$A = L \times W$$

$$330 \text{ sq ft} = L \text{ ft} \times 15 \text{ ft}$$

$$\frac{L \text{ ft} \times 15 \text{ ft}}{15 \text{ ft}} = \frac{330 \text{ ft}^2}{15 \text{ ft}}$$

Divide both sides of equation by 15 ft.

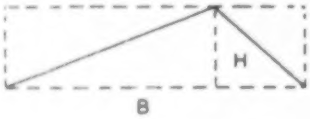
$$L \text{ ft} = \frac{330 \text{ ft}^2}{15 \text{ ft}}$$

$$= 22 \text{ ft}$$

A.22 Triangle

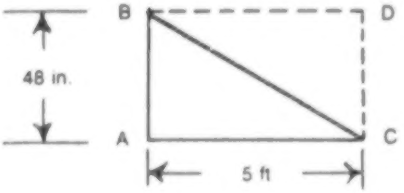
The area of a triangle is equal to one half the base multiplied by the height. This is true for any triangle.

A = ½ B × H



NOTE: The area of *ANY* triangle is equal to ½ the area of the rectangle that can be drawn around it. The area of the rectangle is B × H. The area of the triangle is ½ B × H.

Example: Find the area of triangle ABC.



The first step in the solution is to make all the units the same. In this case, it is easier to change inches to feet.

$$48 \cancel{\text{in}} = 48 \text{ in} \times \frac{1 \text{ ft}}{12 \cancel{\text{in}}} = \frac{48}{12} \text{ ft} = 4 \text{ ft}$$

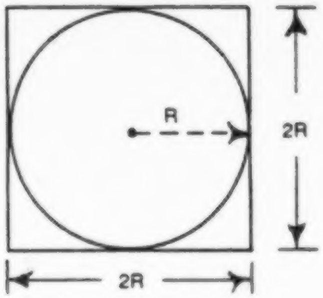
NOTE: All conversions should be calculated in the above manner. Since 1 ft/12 in is equal to unity, or one, multiplying by this factor changes the form of the answer but not its value.

$$\begin{aligned} \text{Area, sq ft} &= \tfrac{1}{2} (\text{Base, ft})(\text{Height, ft}) \\ &= \tfrac{1}{2} \times 5 \text{ ft} \times 4 \text{ ft} \\ &= \frac{20}{2} \text{ ft}^2 \\ &= 10 \text{ sq ft} \end{aligned}$$

NOTE: Triangle ABC is one half the area of rectangle ABCD. The triangle is a special form called a *RIGHT TRIANGLE* since it contains a 90° angle at point A.

A.23 Circle

A square with sides of 2R can be drawn around a circle with a radius of R.



The area of the square is: $A = 2R \times 2R = 4R^2$.

It has been found that the area of any circle inscribed within a square is slightly more than ¾ of the area of the square. More precisely, the area of the preceding circle is:

$$A \text{ circle} = 3\frac{1}{7}R^2 = 3.14\ R^2$$

The formula for the area of a circle is usually written:

$$\boxed{A = \pi R^2}$$

The Greek letter π (pronounced pie) merely substitutes for the value 3.1416.

Since the diameter of any circle is equal to twice the radius, the formula for the area of a circle can be rewritten as follows:

$$A = \pi R^2 = \pi \times R \times R = \pi \times \frac{D}{2} \times \frac{D}{2} = \frac{\pi D^2}{4} = \frac{3.14}{4} D^2 = \boxed{0.785\ D^2}$$

The type of problem and the magnitude of the numbers in a problem will determine which of the two formulas will provide a simpler solution. All of these formulas will give the same results if you use the same number of digits to the right of the decimal point.

Example: What is the area of a circle with a diameter of 20 centimeters?

In this case, the formula using a radius is more convenient since it takes advantage of multiplying by 10.

Area, sq cm = π (R, cm)^2

= 3.14 × 10 cm × 10 cm

= 314 sq cm

Example: What is the area of a clarifier with a 50-foot radius?

In this case, the formula using diameter is more convenient.

Area, sq ft = 0.785 (Diameter, ft)^2

= 0.785 × 100 ft × 100 ft

= 7850 sq ft

Occasionally the operator may be confronted with a problem giving the area and requesting the radius or diameter. This presents the special problem of finding the square root of the number.

Example: The surface area of a circular clarifier is approximately 5000 square feet. What is the diameter?

$A = 0.785\ D^2$, or

Area, sq ft = 0.785 (Diameter, ft)^2

5000 sq ft = 0.785 D^2 — To solve, substitute given values in equation.

$\frac{0.785\ D^2}{0.785} = \frac{5000 \text{ sq ft}}{0.785}$— Divide both sides by 0.785 to find D^2

$D^2 = \frac{5000 \text{ sq ft}}{0.785}$

= 6369 sq ft. Therefore,

D = square root of 6369 sq ft, or

Diameter, ft = $\sqrt{6369 \text{ sq ft}}$.

Punch the $\sqrt{}$ sign on your calculator and get D = 79.8 ft.

Sometimes it is easier to use a trial and error method of finding square roots. Since 80 × 80 = 6400, we know the answer is close to 80 feet.

Try 79 × 79 = 6241

Try 79.5 × 79.5 = 6320.25

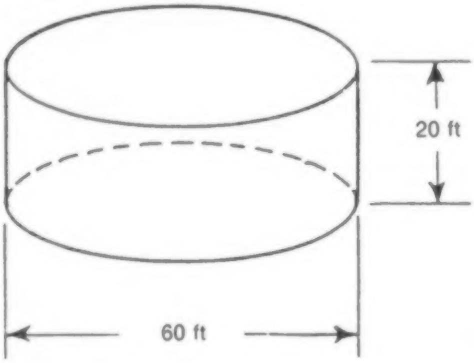
Try 79.8 × 79.8 = 6368.04

The diameter is 79.8 ft, or approximately 80 feet.

A.24 Cylinder

With the formulas presented thus far, it would be a simple matter to find the number of square feet in a room that was to be painted. The length of each wall would be added together and then multiplied by the height of the wall. This would give the surface area of the walls (minus any area for doors and windows). The ceiling area would be found by multiplying length times width and the result added to the wall area gives the total area.

The surface area of a circular cylinder, however, has not been discussed. If we wanted to know how many square feet of surface area are in a tank with a diameter of 60 feet and a height of 20 feet, we could start with the top and bottom.



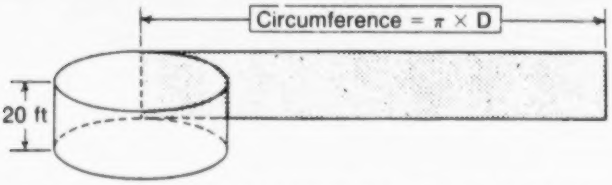
The area of the top and bottom ends are both $\pi \times R^2$

Area, sq ft = 2 ends (π)(Radius, ft)^2

= $2 \times \pi \times (30\text{ ft})^2$

= 5652 sq ft

The surface area of the wall must now be calculated. If we made a vertical cut in the wall and unrolled it, the straightened wall would be the same length as the circumference of the floor and ceiling.



This length has been found to always be $\pi \times D$. In the case of the tank, the length of the wall would be:

Length, ft = (π) (Diameter, ft)

= 3.14×60 ft

= 188.4 ft

Area would be:

A_w sq ft = Length, ft × Height, ft

= 188.4 ft × 20 ft

= 3768 sq ft

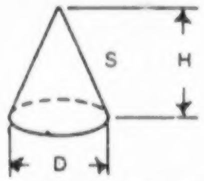
Outside Surface Area to Paint, sq ft = Area of top and bottom, sq ft + Area of wall, sq ft

= 5652 sq ft + 3768 sq ft

= 9420 sq ft

A container has inside and outside surfaces and you may need to paint both of them.

A.25 Cone



The lateral area of a cone is equal to ½ of the slant height (S) multiplied by the circumference of the base.

$$\boxed{A_L = \tfrac{1}{2} S \times \pi \times D = \pi \times S \times R}$$

In this case the slant height is not given, it may be calculated by:

$S = \sqrt{R^2 + H^2}$

Example: Find the entire outside area of a cone with a diameter of 30 inches and a height of 20 inches.

Slant Height, in = $\sqrt{(\text{Radius, in})^2 + (\text{Height, in})^2}$

= $\sqrt{(15\text{ in})^2 + (20\text{ in})^2}$

= $\sqrt{225\text{ in}^2 + 400\text{ in}^2}$

= $\sqrt{625\text{ in}^2}$

= 25 in

Area of Cone, sq in = π (Slant Height, in)(Radius, in)

= 3.14×25 in $\times 15$ in

= 1177.5 sq in

Since the entire area was asked for, the area of the base must be added.

Area, sq in = 0.785 (Diameter, in)^2

= 0.785×30 in $\times 30$ in

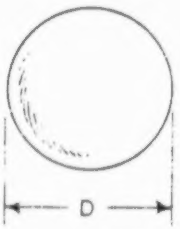
= 706.5 sq in

= Area of Cone, sq in + Area of Bottom, sq in

Total Area, sq in = 1177.5 sq. in + 706.5 sq in

= 1884 sq in

A.26 Sphere



The surface area of a sphere or ball is equal to π multiplied by the diameter squared.

$$\boxed{A_S = \pi D^2}$$

If the radius is used, the formula becomes:

$A_S = \pi D^2 = \pi \times 2R \times 2R = 4\pi R^2$

Example: What is the surface area of a sphere-shaped water tank 20 feet in diameter?

Area, sq ft = π (Diameter, ft)^2

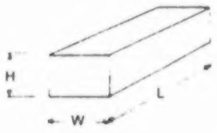
= 3.14×20 ft $\times 20$ ft

= 1256 sq ft

A.3 VOLUMES

A.30 Rectangle

Volumes are measured in three dimensions or in cubic units. To calculate the volume of a rectangle, the area of the base is calculated in square units and then multipled by the height. The formula then becomes:



$$\boxed{V = L \times W \times H}$$

Example: The length of a box is two feet, the width is 15 inches, and the height is 18 inches. Find its volume.

$$\text{Volume, cu ft} = \text{Length, ft} \times \text{Width, ft} \times \text{Height, ft}$$

$$= 2\text{ ft} \times \frac{15\text{ in}}{12\text{ in/ft}} \times \frac{18\text{ in}}{12\text{ in/ft}}$$

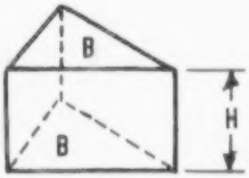
$$= 2\text{ ft} \times 1.25\text{ ft} \times 1.5\text{ ft}$$

$$= 3.75\text{ cu ft}$$

A.31 Prism

The same general rule that applies to the volume of a rectangle also applies to a prism.

$$\boxed{\text{Volume} = \text{Area of Base} \times \text{Height}}$$



Example: Find the volume of a prism with a base area of 10 square feet and a height of 5 feet. (Note that the base of a prism is triangular in shape)

$$\text{Volume, cu ft} = \text{Area of Base, sq ft} \times \text{Height, ft}$$

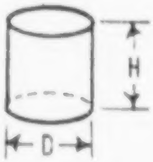
$$= 10\text{ sq ft} \times 5\text{ ft}$$

$$= 50\text{ cu ft}$$

A.32 Cylinder

The volume of a cylinder is equal to the area of the base multiplied by the height.

$$\boxed{V = \pi R^2 \times H = 0.785\ D^2 \times H}$$



Example: A tank has a diameter of 100 feet and a depth of 12 feet. Find the volume.

$$\text{Volume, cu ft} = 0.785 \times (\text{Diameter, ft})^2 \times \text{Height, ft}$$

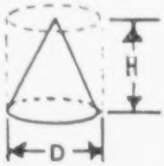
$$= 0.785 \times 100\text{ ft} \times 100\text{ ft} \times 12\text{ ft}$$

$$= 94{,}200\text{ cu ft}$$

A.33 Cone

The volume of a cone is equal to ⅓ the volume of a circular cylinder of the same height and diameter.

$$\boxed{V = \frac{\pi}{3} R^2 \times H}$$



Example: Calculate the additional volume in the cone portion of the tank in Section A.32 if the depth at the center of the tank is 16 ft. H = 16 ft − 12 ft.

$$\text{Volume, cu ft} = \frac{\pi}{3} \times (\text{Radius})^2 \times \text{Height, ft}$$

$$= \frac{\pi}{3} \times 50\text{ ft} \times 50\text{ ft} \times 4\text{ ft}$$

$$= 10{,}500\text{ cu ft}$$

A.34 Sphere

The volume of a sphere is equal to π/6 times the diameter cubed.

$$V = \frac{\pi}{6} \times D^3$$

Example: How much gas can be stored in a sphere with a diameter of 12 feet? (Assume atmospheric pressure.)

$$\text{Volume, cu ft} = \frac{\pi}{6} \times (\text{Diameter, ft})^3$$

$$= \frac{\pi}{\cancel{6}} \times \overset{2}{\cancel{12}}\text{ ft} \times 12\text{ ft} \times 12\text{ ft}$$

$$= 904.32\text{ cubic feet}$$

A.4 METRIC SYSTEM

The two most common systems of weights and measures are the English system and the Metric system. Of these two, the Metric system is more popular with most of the nations of the world. The reason for this is that the Metric system is based on a system of tens and is therefore easier to remember and easier to use than the English system. Even though the basic system in the United States is the English system, the scientific community uses the Metric system almost exclusively. Many organizations have urged, for good reason, that the United States switch to the Metric system. Today the Metric system is gradually becoming the standard system of measurement in the United States.

As the United States changes from the English to the Metric system, some confusion and controversy has developed. For example, which is the correct spelling of the following words:

1. Liter or litre?
2. Meter or metre?

The U.S. National Bureau of Standards, the Water Pollution Control Federation, and the American Water Works Association use litre and metre. The U.S. Government uses liter and meter and accepts no deviations. Some people argue that METRE should be used to measure LENGTH and that METER should be used to measure FLOW RATES (like a water or electric meter). Liter and Meter are used in this manual because this is most consistent with spelling in the United States.

One of the most frequent arguments heard against the U.S. switching to the Metric system was that the costs of switching manufacturing processes would be excessive. Pipe manufacturers have agreed upon the use of a "soft" metric conversion system during the conversion to the Metric system. Past practice in the U.S. has identified some types of pipe by external (outside) diameter while other types are classified by nominal (existing only in name, not real or actual) bore. This means that a six-inch pipe does not have a six-inch inside diameter. With the strict or "hard" metric system, a six-inch pipe would be a 152.4 mm (6 in × 25.4 mm/in) pipe. In the "soft" metric system a six-inch pipe is a 150 mm (6 in × 25 mm/in) pipe. Typical customary and "soft" metric pipe-size designations are shown below:

PIPE-SIZE DESIGNATIONS

Customary, in	2	4	6	8	10	12	15	18
"Soft" Metric, mm	50	100	150	200	250	300	375	450

Customary, in	24	30	36	42	48	60	72	84
"Soft" Metric, mm	600	750	900	1050	1200	1500	1800	2100

In order to study the Metric system, you must know the meanings of the terminology used. Following is a list of Greek and Latin prefixes used in the Metric system.

PREFIXES USED IN THE METRIC SYSTEM

Prefixes	Symbol	Meaning
Micro	μ	1/1 000 000 or 0.000 001
Milli	m	1/1000 or 0.001
Centi	c	1/100 or 0.01
Deci	d	1/10 or 0.1
Unit		1
Deka	da	10
Hecto	h	100
Kilo	k	1000
Mega	M	1 000 000

A.40 Measures of Length

The basic measure of length is the meter.

1 kilometer (km) = 1000 meters (m)
1 meter (m) = 100 centimeters (cm)
1 centimeter (cm) = 10 millimeters (mm)

Kilometers are usually used in place of miles, meters are used in place of feet and yards, centimeters are used in place of inches and millimeters are used for inches and fractions of an inch.

LENGTH EQUIVALENTS

1 kilometer	= 0.621 mile	1 mile	= 1.64 kilometers
1 meter	= 3.28 feet	1 foot	= 0.305 meter
1 meter	= 39.37 inches	1 inch	= 0.0254 meter
1 centimeter	= 0.3937 inch	1 inch	= 2.54 centimeters
1 millimeter	= 0.0394 inch	1 inch	= 25.4 millimeters

NOTE: The above equivalents are reciprocals. If one equivalent is given, the reverse can be obtained by division. For instance, if one meter equals 3.28 feet, one foot equals 1/3.28 meter, or 0.305 meter.

A.41 Measures of Capacity or Volume

The basic measure of capacity in the Metric system is the liter. For measurement of large quantities the cubic meter is sometimes used.

1 kiloliter (k*L*) = 1000 liters (*L*) = 1 cu meter (m^3)

1 liter (*L*) = 1000 milliliters (m*L*)

Kiloliters, or cubic meters, are used to measure capacity of large storage tanks or reservoirs in place of cubic feet or gallons. Liters are used in place of gallons or quarts. Milliliters are used in place of quarts, pints, or ounces.

CAPACITY EQUIVALENTS

1 kiloliter	= 264.2 gallons	1 gallon	= 0.003785 kiloliter
1 liter	= 1.057 quarts	1 quart	= 0.946 liter
1 liter	= 0.2642 gallons	1 gallon	= 3.785 liters
1 milliliter	= 0.0353 ounce	1 ounce	= 29.57 milliliters

A.42 Measures of Weight

The basic unit of weight in the Metric system is the gram. One cubic centimeter of water at maximum density weighs one gram, and thus there is a direct, simple relation between volume of water and weight in the Metric system.

1 kilogram (kg) = 1000 grams (gm)
1 gram (gm) = 1000 milligrams (mg)
1 milligram (mg) = 1000 micrograms (μg)

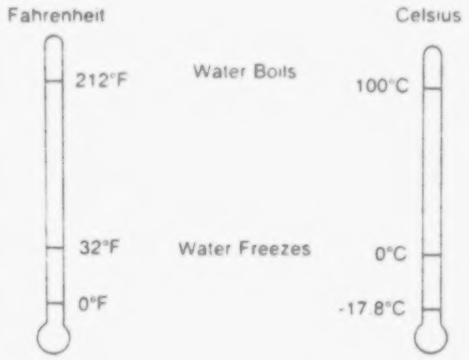
Grams are usually used in place of ounces, and kilograms are used in place of pounds.

WEIGHT EQUIVALENTS

1 kilogram	= 2.205 pounds	1 pound	= 0.4536 kilogram
1 gram	= 0.0022 pound	1 pound	= 453.6 grams
1 gram	= 0.0353 ounce	1 ounce	= 28.35 grams
1 gram	= 15.43 grains	1 grain	= 0.0648 gram

A.43 Temperature

Just as the operator should become familiar with the Metric system, you should also become familiar with the centigrade (Celsius) scale for measuring temperature. There is nothing magical about the centigrade scale — it is simply a different size than the Fahrenheit scale. The two scales compare as follows:



The two scales are related in the following manner:

$$\boxed{\begin{array}{ll} \text{Fahrenheit} & = (^\circ C \times 9/5) + 32^\circ \\ \text{Celsius} & = (^\circ F - 32^\circ) \times 5/9 \end{array}}$$

Example: Convert 20° Celsius to Fahrenheit.

$$F = (^\circ C \times 9/5) + 32^\circ$$

$$F = (20^\circ \times 9/5) + 32^\circ$$

$$F = \frac{180^\circ}{5} + 32^\circ$$

$$= 36^\circ + 32^\circ$$

$$= 68^\circ F$$

Example: Convert $-10^\circ C$ to °F.

$$F = (-10^\circ \times 9/5) + 32^\circ$$

$$F = -90^\circ/5 + 32^\circ$$

$$= -18^\circ + 32^\circ$$

$$= 14^\circ F$$

Example: Convert −13°F to °C.

$$C = (°F - 32°) \times \frac{5}{9}$$

$$C = (-13° - 32°) \times \frac{5}{9}$$

$$= -45° \times \frac{5}{9}$$

$$= -5° \times 5$$

$$= -25°C$$

A.44 Milligrams per Liter

Milligrams per liter (mg/*L*) is a unit of measurement used in laboratory and scientific work to indicate very small concentrations of dilutions. Since water contains small concentrations of dissolved substances and solids, and since small amounts of chemical compounds are sometimes used in water treatment processes, the term milligrams per liter is also common in treatment plants. It is a weight/volume relationship.

As previously discussed:

1000 liters = 1 cubic meter = 1,000,000 cubic centimeters.

Therefore

1 liter = 1000 cubic centimeters

Since one cubic centimeter of water weighs one gram.

1 liter of water = 1000 grams or 1,000,000 milligrams

$$\boxed{\frac{1 \text{ milligram}}{\text{liter}} = \frac{1 \text{ milligram}}{1{,}000{,}000 \text{ milligrams}} = \frac{1 \text{ part}}{\text{million parts}} = \text{1 part per million (ppm)}}$$

Milligrams per liter and parts per million (parts) may be used interchangeably as long as the liquid density is 1.0 gm/cu cm or 62.43 lb/cu ft. A concentration of 1 milligram/liter (mg/*L*) or 1 ppm means that there is 1 part of substance by weight for every 1 million parts of water. A concentration of 10 mg/*L* would mean 10 parts of substance per million parts of water.

To get an idea of how small 1 mg/*L* is, divide the numerator and denominator of the fraction by 10,000. This, of course, does not change its value since, 10,000 ÷ 10,000 is equal to one.

$$\boxed{1\,\frac{\text{mg}}{L} = \frac{1 \text{ mg}}{1{,}000{,}000 \text{ mg}} = \frac{1/10{,}000 \text{ mg}}{1{,}000{,}000/10{,}000 \text{ mg}} = \frac{0.0001 \text{ mg}}{100 \text{ mg}} = 0.0001\%}$$

Therefore, 1 mg/*L* is equal to one ten-thousandth of a percent, or

1% is equal to 10,000 mg/*L*

To convert mg/*L* to %, move the decimal point four places or numbers to the left.

Working problems using milligrams per liter or parts per million is a part of everyday operation in most wastewater treatment plants.

A.45 Example Problems

Example: A plant effluent flowing at a rate of five million pounds per day contains 15 mg/*L* of solids. How many pounds of solids will be discharged per day?

$$15 \text{ mg}/L = \frac{15 \text{ lbs solids}}{\text{million lbs water}}$$

$$\text{Solids Discharged, lbs/day} = \text{Concentration, lbs/M lbs} \times \text{Flow, lbs/day}$$

$$= \frac{15 \text{ lbs}}{\cancel{\text{million lbs}}} \times \frac{5\ \cancel{\text{million lbs}}}{\text{day}}$$

$$= 75 \text{ lbs/day}$$

There is one thing that is unusual about the above problem and that is the flow is reported in pounds per day. In most treatment plants, flow is reported in terms of gallons per minute or gallons per day. To convert these flow figures to weight, an additional conversion factor is needed. It has been found that one gallon of water (and wastewater, since it is almost all water) weighs 8.34 pounds. Using this factor, it is possible to convert flow in gallons per day to flow in pounds per day.

Example: A plant influent of 3.5 million gallons per day (MGD) contains 200 mg/*L* BOD. How many pounds of BOD enter the plant per day?

$$\text{Flow, lbs/day} = \text{Flow, } \frac{\text{M gal}}{\text{day}} \times \frac{8.34 \text{ lb}}{\text{gal}}$$

$$= \frac{3.5 \text{ million } \cancel{\text{gal}}}{\text{day}} \times \frac{8.34 \text{ lbs}}{\cancel{\text{gal}}}$$

$$= 29.19 \text{ million lbs/day}$$

$$\text{BOD Loading, lbs/day} = \text{Level, mg}/L \times \text{Flow, M lb/day}$$

$$= \frac{200\ \cancel{\text{mg}}^*}{\cancel{\text{million mg}}} \times \frac{29.19\ \cancel{\text{million}} \text{ lbs}}{\text{day}}$$

$$= 5838 \text{ lbs/day}$$

---

* Remember that $\frac{1 \text{ mg}}{\text{M mg}} = \frac{1 \text{ lb.}}{\text{M lb}}$ They are identical ratios.

In solving the above problem, a relation was used that is most important to understand and commit to memory.

$$\boxed{\text{Lbs/day} = \text{Conc., mg}/L \times \text{Flow, MGD} \times 8.34 \text{ lb/gal}}$$

Example: A chlorinator is set to feed 50 pounds of chlorine per day to a flow of 0.8 MGD. What is the chlorine dose in mg/*L*?

$$\text{Conc. or Dose, mg}/L = \frac{\text{lbs/day}}{\text{MGD} \times 8.34 \text{ lb/gal}}$$

$$= \frac{50 \text{ lb/day}}{0.80 \text{ MG/day} \times 8.34 \text{ lb/gal}}$$

$$= \frac{50 \text{ lb}}{6.672 \text{ M lb}}$$

$$= 7.5 \text{ mg}/L, \text{ or } 7.5 \text{ ppm}$$

Example: Treated effluent is pumped to a spray disposal field by a pump that delivers 500 gallons per minute. Suspended solids in the effluent average 10 mg/*L*. What is the total weight of suspended solids deposited on the spray field during a 24-hour day of continuous pumping?

$$\text{Flow, MGD} = \text{Flow, gpm} \times 60 \text{ min/hr} \times 24 \text{ hr/day}$$

$$= \frac{500 \text{ gal}}{\cancel{\text{min}}} \times \frac{60\ \cancel{\text{min}}}{\cancel{\text{hr}}} \times \frac{24\ \cancel{\text{hr}}}{\text{day}}$$

$$= 720{,}000 \text{ gal/day}$$

$$= 0.72 \text{ MGD}$$

$$\text{Weight of Solids, lbs/day} = \text{Conc., mg}/L \times \text{Flow, MGD} \times 8.34\ \text{lb/gal}$$

$$= \frac{10\ \cancel{\text{mg}}}{\text{M}\ \cancel{\text{mg}}} \times \frac{0.72\ \text{M}\ \cancel{\text{gal}}}{\text{day}} \times \frac{8.34\ \text{lb}}{\cancel{\text{gal}}}$$

$$= 60.048\ \text{lbs/day or about 60 lbs/day}$$

A.5 WEIGHT-VOLUME RELATIONS

Another factor for the operator to remember, in addition to the weight of a gallon of water, is the weight of a cubic foot of water. One cubic foot of water weighs 62.4 lbs. If these two weights are divided, it is possible to determine the number of gallons in a cubic foot.

$$\frac{62.4\ \cancel{\text{pounds}}/\text{cu ft}}{8.34\ \cancel{\text{pounds}}/\text{gal}} = 7.48\ \text{gal/cu ft}$$

Thus we have another very important relationship to commit to memory.

$$\boxed{8.34\ \text{lb/gal} \times 7.48\ \text{gal/cu ft} = 62.4\ \text{lb/cu ft}}$$

It is only necessary to remember two of the above items since the third may be found by calculation. For most problems, 8⅓ lbs/gal and 7½ gal/cu ft will provide sufficient accuracy.

Example: Change 1000 cu ft of water to gallons.

1000 cu ft × 7.48 gal/cu ft = 7480 gallons

Example: What is the weight of three cubic feet of water?

62.4 lb/cu ft × 3 cu ft = 187.2 lbs

Example: The net weight of a tank of water is 750 lbs. How many gallons does it contain?

$$\frac{750\ \cancel{\text{lb}}}{8.34\ \cancel{\text{lb}}/\text{gal}} = 90\ \text{gals}$$

A.6 FORCE, PRESSURE, AND HEAD

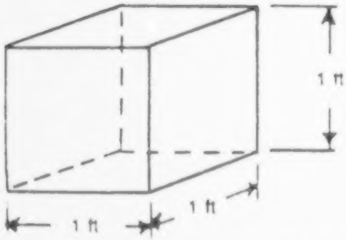
In order to study the forces and pressures involved in fluid flow, it is first necessary to define the terms used.

FORCE:	The push exerted by water on any surface being used to confine it. Force is usually expressed in pounds, tons, grams, or kilograms.
PRESSURE:	The force per unit area. Pressure can be expressed in many ways, but the most common term is pounds per square inch (psi).
HEAD:	Vertical distance from the water surface to a reference point below the surface. Usually expressed in feet or meters.

An *EXAMPLE* should serve to illustrate these terms.

If water were poured into a one-foot cubical container, the *FORCE* acting on the bottom of the container would be 62.4 pounds.

The *PRESSURE* acting on the bottom would be 62.4 pounds per square foot. The area of the bottom is also 12 in × 12 in = 144 in^2. Therefore, the pressure may also be expressed as:



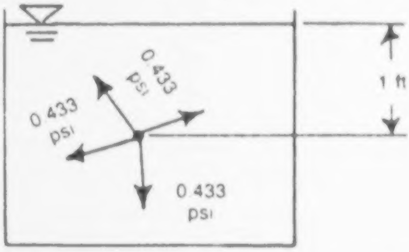
$$\text{Pressure, psi} = \frac{62.4\ \text{lb}}{\text{sq ft}} = \frac{62.4\ \text{lb/sq ft}}{144\ \text{sq in/sq ft}}$$

$$= 0.433\ \text{lb/sq in}$$

$$= 0.433\ \text{psi}$$

Since the height of the container is one foot, the *HEAD* would be one foot.

The pressure in any vessel at one foot of depth or one foot of head is 0.433 psi acting in any direction.



If the depth of water in the previous example were increased to two feet, the pressure would be:

$$p = \frac{2\ (62.4\ \text{lb})}{144\ \text{sq in}} = \frac{124.8\ \text{lb}}{144\ \text{sq in}} = 0.866\ \text{psi}$$

Therefore we can see that for every foot of head, the pressure increases by 0.433 psi. Thus, the general formula for pressure becomes:

$$\boxed{\text{p, psi} = 0.433\ (\text{H, ft})}$$

H = feet of head

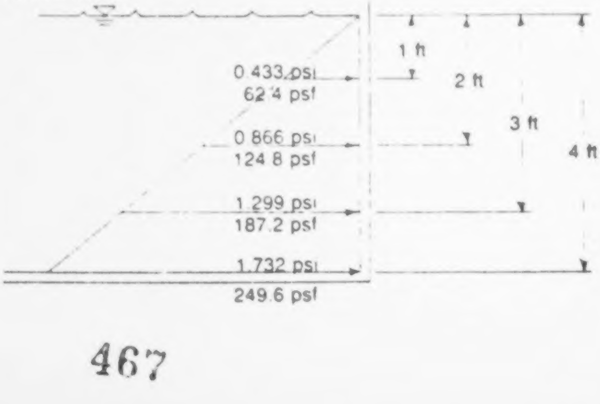
p = pounds per square *INCH* of pressure

$$\boxed{\text{P, lb/sq ft} = 62.4\ (\text{H, ft})}$$

H = feet of head

P = pounds per square *FOOT* of pressure

We can now draw a diagram of the pressure acting on the side of a tank. Assume a four-foot deep tank. The pressures shown on the tank are gage pressures. These pressures do not include the atmospheric pressure acting on the surface of the water.



$p_0 = 0.433 \times 0 = 0.0$ psi $P_0 = 62.4 \times 0 = 0.0$ lb/sq ft
$p_1 = 0.433 \times 1 = 0.433$ psi $P_1 = 62.4 \times 1 = 62.4$ lb/sq ft
$p_2 = 0.433 \times 2 = 0.866$ psi $P_2 = 62.4 \times 2 = 124.8$ lb/sq ft
$p_3 = 0.433 \times 3 = 1.299$ psi $P_3 = 62.4 \times 3 = 187.2$ lb/sq ft
$p_4 = 0.433 \times 4 = 1.732$ psi $P_4 = 62.4 \times 4 = 249.6$ lb/sq ft

The average *PRESSURE* acting on the tank wall is 1.732 psi/2 = 0.866 psi, or 249.2 psf/2 = 124.8 psf. We divided by two to obtain the average pressure because there is zero pressure at the top and 1.732 psi pressure on the bottom of the wall.

If the wall were five feet long, the pressure would be acting over the entire 20 square foot (5 ft × 4 ft) area of the wall. The total force acting to push the wall would be:

$$\begin{aligned}\text{Force, lb} &= (\text{Pressure, lb/sq ft})(\text{Area, sq ft})\\ &= 124.8\text{ lb/sq ft} \times 20\text{ sq ft}\\ &= 2496\text{ lbs}\end{aligned}$$

If the pressure in psi were used, the problem would be similar:

$$\begin{aligned}\text{Force, lb} &= (\text{Pressure, lb/sq in})(\text{Area, sq in})\\ &= 0.866\text{ psi} \times 48\text{ in} \times 60\text{ in}\\ &= 2494\text{ lb}^*\end{aligned}$$

---

* Difference in answer due to rounding off of decimal points.

The general formula, then, for finding the total force acting on a side wall of a tank is:

$$\boxed{F = 31.2 \times H^2 \times L}$$

F = force in pounds
H = head in feet
L = length of wall in feet
31.2 = constant with units of lbs/cu ft and considers the fact that the force results from H/2 or half the depth of the water which is the average depth. The force is exerted at H/3 from the bottom.

Example: Find the force acting on a five-foot long wall in a four-foot deep tank.

$$\begin{aligned}\text{Force, lb} &= 31.2\ (\text{Head, ft})^2\ (\text{Length, ft})\\ &= 31.2\text{ lb/cu ft} \times (4\text{ ft})^2 \times 5\text{ ft}\\ &= 2496\text{ lbs}\end{aligned}$$

Occasionally an operator is warned: *NEVER EMPTY A TANK DURING PERIODS OF HIGH GROUNDWATER.* Why? The pressure on the bottom of the tank caused by the water surrounding the tank will tend to float the tank like a cork if the upward force of the water is greater than the weight of the tank.

$$\boxed{F = 62.4 \times H \times A}$$

F = upward force in pounds
H = head of water on tank bottom in feet
A = area of bottom of tank in square feet
62.4 = a constant with units of lbs/cu ft

This formula is approximately true if the tank doesn't crack, leak, or start to float.

Example: Find the upward force on the bottom of an empty tank caused by a groundwater depth of 8 feet above the tank bottom. The tank is 20 ft wide and 40 ft long.

$$\begin{aligned}\text{Force, lb} &= 62.4\ (\text{Head, ft})(\text{Area, sq ft})\\ &= 62.4\text{ lb/cu ft} \times 8\text{ ft} \times 20\text{ ft} \times 40\text{ ft}\\ &= 399{,}400\text{ lb}\end{aligned}$$

A.7 VELOCITY AND FLOW RATE

A.70 Velocity

The velocity of a particle or substance is the speed at which it is moving. It is expressed by indicating the length of travel and how long it takes to cover the distance. Velocity can be expressed in almost any distance and time units. For instance, a car may be traveling at a rate of 280 miles per five hours. However, it is normal to express the distance traveled per unit time. The above example would then become:

$$\begin{aligned}\text{Velocity, mi/hr} &= \frac{280\text{ miles}}{5\text{ hours}}\\ &= 56\text{ miles/hour}\end{aligned}$$

The velocity of water in a channel, pipe, or other conduit can be expressed in the same way. If the particle of water travels 600 feet in five minutes, the velocity is:

$$\begin{aligned}\text{Velocity, ft/min} &= \frac{\text{distance, ft}}{\text{time, minutes}}\\ &= \frac{600\text{ ft}}{5\text{ min}}\\ &= 120\text{ ft/min}\end{aligned}$$

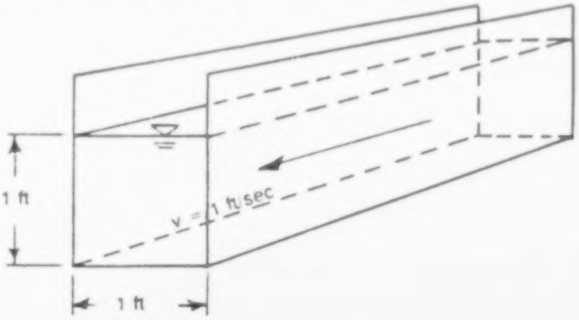
If you wish to express the velocity in feet per second, multiply by 1 min/60 seconds.

NOTE: $\frac{1\text{ minute}}{60\text{ seconds}}$ is like $\frac{1}{1}$ and does not change the relative value of the answer. It only changes the form of the answer.

$$\begin{aligned}\text{Velocity, ft/sec} &= (\text{Velocity, ft/min})(1\text{ min}/60\text{ sec})\\ &= \frac{120\text{ ft}}{\cancel{\text{min}}} \times \frac{1\ \cancel{\text{min}}}{60\text{ sec}}\\ &= \frac{120\text{ ft}}{60\text{ sec}}\\ &= 2\text{ ft/sec}\end{aligned}$$

A.71 Flow Rate

If water in a one-foot wide channel is one foot deep, then the cross sectional area of the channel is 1 ft × 1 ft = 1 sq ft.



If the velocity in this channel is 1 ft per second, then each second a body of water 1 sq ft in area and 1 ft long will pass a given point. The volume of this body of water would be 1 cubic foot. Since one cubic foot of water would pass by every second, the flow rate would be equal to 1 cubic foot per second, or 1 cfs.

To obtain the flow rate in the above example the velocity was multiplied by the cross sectional area. This is another important general formula.

$\boxed{Q = V \times A}$

Q = flow rate, cfs or cu ft/sec

V = velocity, ft/sec

A = area, sq ft

Example: A rectangular channel 3 feet wide contains water 2 feet deep and flowing at a velocity of 1.5 feet per second. What is the flow rate in cfs?

$$Q = V \times A$$

$$\begin{aligned}\text{Flow rate, cfs} &= \text{Velocity, ft/sec} \times \text{Area, sq ft}\\ &= 1.5\ \text{ft/sec} \times 3\ \text{ft} \times 2\ \text{ft}\\ &= 9\ \text{cu ft/sec}\end{aligned}$$

Example: Flow in a 2.5 foot wide channel is 1.4 ft deep and measures 11.2 cfs. What is the average velocity?

In this problem we want to find the velocity. Therefore, we must rearrange the general formula to solve for velocity.

$$V = \frac{Q}{A}$$

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Flow Rate, cu ft/sec}}{\text{Area, sq ft}}\\ &= \frac{11.2\ \text{cu ft/sec}}{2.5\ \text{ft} \times 1.4\ \text{ft}}\\ &= \frac{11.2\ \text{ft/sec}}{3.5}\\ &= 3.2\ \text{ft/sec}\end{aligned}$$

Example: Flow in an 8-inch pipe is 500 GPM. What is the average velocity?

$$\begin{aligned}\text{Area, sq ft} &= 0.785\ (\text{Diameter, ft})^2\\ &= 0.785\ (8/12\ \text{ft})^2\\ &= 0.785\ (\tfrac{2}{3}\ \text{ft})^2\\ &= 0.785\ (\tfrac{2}{3}\ \text{ft})(\tfrac{2}{3}\ \text{ft})\\ &= 0.785\ (4/9\ \text{ft}^2)\\ &= 0.35\ \text{sq ft}\end{aligned}$$

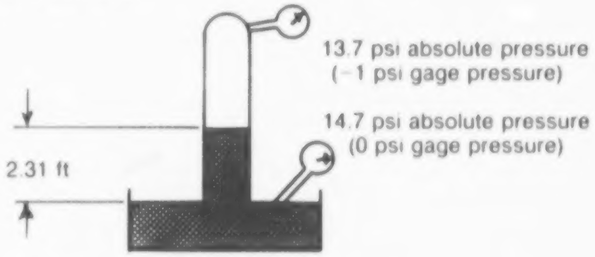
$$\begin{aligned}\text{Flow, cfs} &= \text{Flow, gal/min} \times \frac{\text{cu ft}}{7.48\ \text{gal}} \times \frac{1\ \text{min}}{60\ \text{sec}}\\ &= \frac{500\ \text{gal}}{\text{min}} \times \frac{\text{cu ft}}{7.48\ \text{gal}} \times \frac{1\ \text{min}}{60\ \text{sec}}\\ &= \frac{500\ \text{cu ft}}{448.8\ \text{sec}}\\ &= 1.114\ \text{cfs}\end{aligned}$$

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Flow, cu ft/sec}}{\text{Area, sq ft}}\\ &= \frac{1.114\ \text{ft}^3\text{/sec}}{0.35\ \text{ft}^2}\\ &= 3.18\ \text{ft/sec}\end{aligned}$$

A.8 PUMPS

A.80 Pressure

Atmospheric pressure at sea level is approximately 14.7 psi. This pressure acts in all directions and on all objects. If a tube is placed upside down in a basin of water and a 1 psi partial vacuum is drawn on the tube, the water in the tube will rise 2.31 feet.



NOTE: 1 ft of water = 0.433 psi; therefore,

$$1\ \text{psi} = \frac{1}{0.433}\ \text{ft} = 2.31\ \text{ft of water}$$

The action of the partial vacuum is what gets water out of a sump or well and up to a pump. It is not sucked up, but it is pushed up by atmospheric pressure on the water surface in the sump. If a complete vacuum could be drawn, the water would rise 2.31 × 14.7 = 33.9 feet; but this is impossible to achieve. The practical limit of the suction lift of a positive displacement pump is about 22 feet, and that of a centrifugal pump is 15 feet.

A.81 Work

Work can be expressed as lifting a weight a certain vertical distance. It is usually defined in terms of foot-pounds.

Example: A 165-pound man runs up a flight of stairs 20 feet high. How much work did he do?

$$\begin{aligned}\text{Work, ft-lb} &= \text{Weight, lb} \times \text{Height, ft}\\ &= 165\ \text{lb} \times 20\ \text{ft}\\ &= 3300\ \text{ft-lb}\end{aligned}$$

A.82 Power

Power is a rate of doing work and is usually expressed in foot-pounds per minute.

Example: If the man in the above example runs up the stairs in three seconds, how much power has he exerted?

$$\begin{aligned}\text{Power, ft-lbs/sec} &= \frac{\text{Work, ft-lb}}{\text{Time, sec}}\\ &= \frac{3300\ \text{ft-lbs}}{3\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{\text{minute}}\\ &= 66{,}000\ \text{ft-lb/min}\end{aligned}$$

A.83 Horsepower

Horsepower is also a unit of power. One horsepower is defined as 33,000 ft-lbs per minute or 746 watts.

Example: How much horsepower has the man in the previous example exerted as he climbs the stairs?

$$\text{Horsepower, HP} = (\text{Power, ft-lb/min})\left(\frac{\text{HP}}{33{,}000\text{ ft-lb/min}}\right)$$

$$= 66{,}000\text{ ft-lb/min} \times \frac{\text{Horsepower}}{33{,}000\text{ ft-lb/min}}$$

$$= 2\text{ HP}$$

Work is also done by lifting water. If the flow from a pump is converted to a weight of water and multiplied by the vertical distance it is lifted, the amount of work or power can be obtained.

$$\text{Horsepower, HP} = \frac{\text{Flow, gal}}{\text{min}} \times \text{Lift, ft} \times \frac{8.34\text{ lb}}{\text{gal}} \times \frac{\text{Horsepower}}{33{,}000\text{ ft-lb/min}}$$

Solving the above relation, the amount of horsepower necessary to lift the water is obtained. This is called water horsepower.

$$\text{Water, HP} = \frac{(\text{Flow, GPM})(\text{H, ft})}{3960^{*}}$$

However, since pumps are not 100% efficient (they cannot transmit all the power put into them), the horsepower supplied to a pump is greater than the water horsepower. Horsepower supplied to the pump is called brake horsepower.

$$\boxed{\text{Brake, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p}}$$

E_p = Efficiency of Pump (Usual range 50-85%, depending on type and size of pump)

Motors are also not 100% efficient; therefore, the power supplied to the motor is greater than the motor transmits.

$$\boxed{\text{Motor, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p \times E_m}}$$

E_m = Efficiency of motor (Usual range 80-95%, depending on type and size of motor)

The above formulas have been developed for the pumping of water and wastewater which have a specific gravity of 1.0. If other liquids are to be pumped, the formulas must be multiplied by the specific gravity of the liquid.

Example: A flow of 500 GPM of water is to be pumped against a total head of 100 feet by a pump with an efficiency of 70%. What is the pump horsepower?

$$\text{Brake, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p}$$

$$= \frac{500 \times 100}{3960 \times 0.70}$$

$$= 18\text{ HP}$$

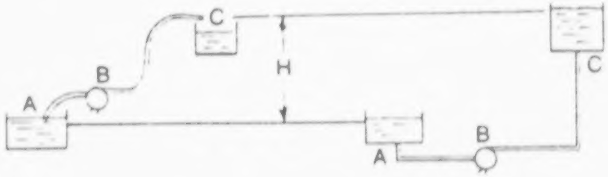
Example: Find the horsepower required to pump gasoline (specific gravity = 0.75) in the above problem.

$$\text{Brake, HP} = \frac{500 \times 100 \times 0.75}{3960 \times 0.70}$$

$$= 13.5\text{ HP}$$ (gasoline is lighter and requires less horsepower)

A.84 Head

Basically, the head that a pump must work against is determined by measuring the vertical distance between the two water surfaces, or the distance the water must be lifted. This is called the static head. Two typical conditions for lifting water are shown below.



If a pump were designed in the above examples to pump only against head H, the water would never reach the intended point. The reason for this is that the water encounters friction in the pipelines. Friction depends on the roughness and length of pipe, the pipe diameter, and the flow velocity. The turbulence caused at the pipe entrance (point A); the pump (point B); the pipe exit (point C); and at each elbow, bend, or transition also adds to these friction losses. Tables and charts are available in Section A.88 for calculation of these friction losses so they may be added to the measured or static head to obtain the total head. For short runs of pipe which do not have high velocities, the friction losses are generally less than 10 percent of the static head.

Example: A pump is to be located eight feet above a wet well and must lift 1.8 MGD another 50 feet to a storage reservoir. If the pump has an efficiency of 75% and the motor an efficiency of 90%, what is the cost of the power consumed if one kilowatt hour costs 4 cents?

Since we are not given the length or size of pipe and the number of elbows or bends, we will assume friction to be 10% of static head.

$$\text{Static Head, ft} = \text{Suction Lift, ft} + \text{Discharge Head, ft}$$

$$= 8\text{ ft} + 50\text{ ft}$$

$$= 58\text{ ft}$$

$$\text{Friction Losses, ft} = 0.1\ (\text{Static Head, ft})$$

$$= 0.1\ (58\text{ ft})$$

$$= 5.8\text{ ft}$$

$$\text{Total Dynamic Head, ft} = \text{Static Head, ft} + \text{Friction Losses, ft}$$

$$= 58\text{ ft} + 5.8\text{ ft}$$

$$= 63.8\text{ ft}$$

$$\text{Flow, GPM} = \frac{1{,}800{,}000\text{ gal}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{24\ \cancel{\text{hr}}} \times \frac{1\ \cancel{\text{hr}}}{60\text{ min}}$$

$$= 1250\text{ GPM}$$ (assuming pump runs 24 hours per day)

$$^{*}\ \frac{8.34\text{ lb}}{\text{gal}} \times \frac{\text{HP}}{33{,}000\text{ ft-lb/min}} = \frac{1}{3960}$$

1 gallon weighs 8.34 pounds and 1 horsepower is the same as 33,000 ft-lb/min.

H or Head in feet is the same as Lift in feet.

$$\text{Motor, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p \times E_m}$$

$$= \frac{1250 \times 63.8}{3960 \times 0.75 \times 0.9}$$

$$= 30 \text{ HP}$$

$$\text{Kilowatt-hrs} = 30 \cancel{\text{HP}} \times 24 \text{ hrs/day} \times 0.746 \text{ kw}/\cancel{\text{HP}}^{*}$$

$$= 537 \text{ kilowatt-hrs/day}$$

$$\text{Cost} = \text{KWH} \times \$0.04/\text{KWH}$$

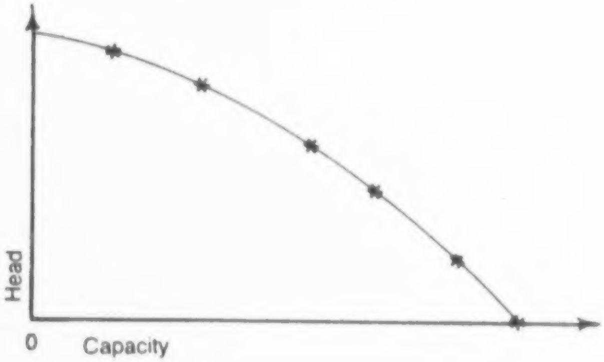
$$= 537 \times 0.04$$

$$= \$21.48/\text{day}$$

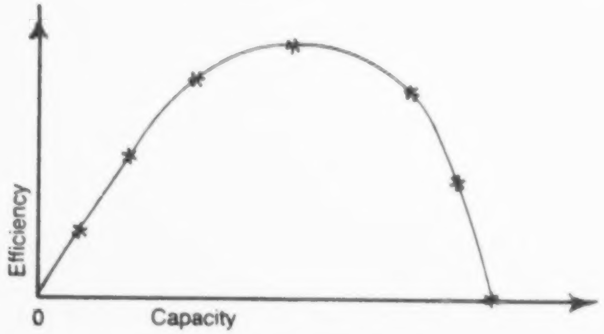
A.85 Pump Characteristics

The discharge of a centrifugal pump, unlike a positive displacement pump, can be made to vary from zero to a maximum capacity which depends on the speed, head, power, and specific impeller design. The interrelation of capacity, efficiency, head, and power is known as the characteristics of the pump.

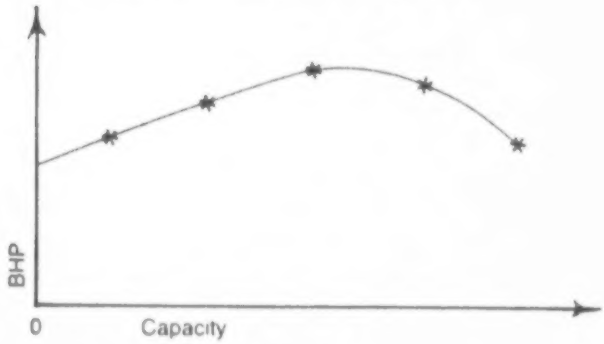
The first relation normally looked at when searching for a pump is the head vs. capacity. The head of a centrifugal pump normally rises as the capacity is reduced. If the values are plotted on a graph they appear as follows:



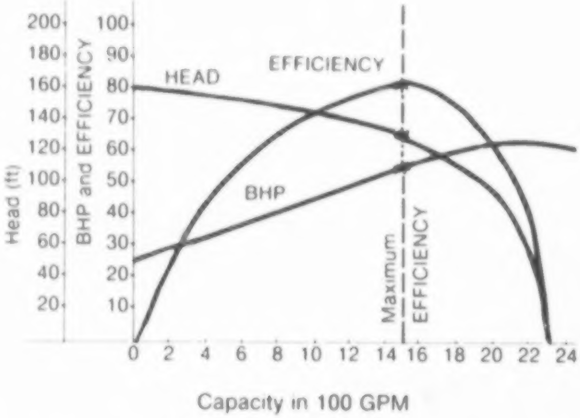
Another important characteristic is the pump efficiency. It begins from zero at no discharge, increases to a maximum, and then drops as the capacity is increased. Following is a graph of efficiency vs. capacity:



The last important characteristic is the brake horsepower or the power input to the pump. The brake horsepower usually increases with increasing capacity until it reaches a maximum, then it normally reduces slightly.



These pump characteristic curves are quite important. Pump sizes are normally picked from these curves rather than calculations. For ease of reading, the three characteristic curves are normally plotted together. A typical graph of pump characteristics is shown as follows:



The curves show that the maximum efficiency for the particular pump in question occurs at approximately 1475 GPM, a head of 132 feet, and a brake horsepower of 58. Operating at this point the pump has an efficiency of approximately 85%. This can be verified by calculation.

$$\text{BHP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E}$$

As previously explained, a number can be written over one without changing its value:

$$\frac{\text{BHP}}{1} = \frac{\text{GPM} \times \text{H}}{3960 \times E}$$

Since the formula is now in ratio form, it can be cross multiplied.

$$\text{BHP} \times 3960 \times E = \text{GPM} \times \text{H} \times 1$$

Solving for E,

$$E = \frac{\text{GPM} \times \text{H}}{3960 \times \text{BHP}}$$

$$E = \frac{1475 \text{ GPM} \times 132 \text{ ft}}{3960 \times 58 \text{ HP}}$$

$$= 0.85 \text{ or } 85\% \text{ (Check)}$$

---

* See Conversion Tables — Section A.10, "Power."

The preceding is only a brief description of pumps to familiarize the operator with their characteristics. The operator does not normally specify the type and size of pump needed at a plant. If a pump is needed, the operator should be able to supply the information necessary for a pump supplier to provide the best possible pump for the lowest cost. Some of the information needed includes:

1. Flow range desired
2. Head conditions
   a. Suction head or lift
   b. Pipe and fitting friction head
   c. Discharge head
3. Type of fluid pumped and temperature
4. Pump location

A.86 Evaluation of Pump Performance

1. Capacity

Sometimes it is necessary to determine the capacity of a pump. This can be accomplished by determining the time it takes a pump to fill or empty a portion of a wet well or diversion box when all inflow is blocked off.

EXAMPLE:

a. Measure the size of the wet well.

Length = 10 ft

Width = 10 ft

Depth = 5 ft (We will measure the time it takes to lower the well a distance of five feet)

$$\text{Volume, cu ft} = \text{L, ft} \times \text{W, ft} \times \text{D, ft}$$

$$= 10 \text{ ft} \times 10 \text{ ft} \times 5 \text{ ft}$$

$$= 500 \text{ cu ft}$$

b. Record time for water to drop five feet in wet well.

Time = 10 minutes 30 seconds
= 10.5 minutes

c. Calculate pumping rate or capacity.

$$\text{Pumping Rate, GPM} = \frac{\text{Volume, gallons}}{\text{Time, minutes}}$$

$$= \frac{(500 \text{ cu ft})(7.5 \text{ gal/cu ft})}{10.5 \text{ min}}$$

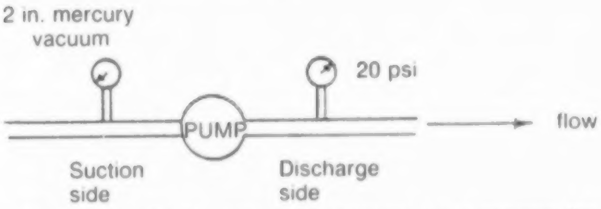
$$= \frac{3750}{10.5}$$

$$= 357 \text{ GPM}$$

If you know the total dynamic head and have the pump's performance curves, you can determine if the pump is delivering at design capacity. If not, try to determine the cause (see Chapter 15, "Maintenance"). After a pump overhaul, the pump's actual performance (flow, head, power and efficiency) should be compared with the pump manufacturer's performance curves. This procedure for calculating the rate of filling or emptying of a wet well or diversion box can be used to calibrate flow meters.

2. Efficiency

To estimate the efficiency of the pump in the previous example, the total head must be known. This head may be estimated by measuring the suction and discharge pressure. Assume these were measured as follows:



No additional information is necessary if we assume the pressure gages are at the same height and the pipe diameters are the same. Both pressure readings must be converted to feet.

$$\text{Suction Lift, ft} = 2 \text{ in Mercury} \times \frac{1.133 \text{ ft water}^*}{1 \text{ in Mercury}}$$

$$= 2.27 \text{ ft}$$

$$\text{Discharge Head, ft} = 20 \text{ psi} \times 2.31 \text{ ft/psi}^*$$

$$= 46.20 \text{ ft}$$

$$\text{Total Head, ft} = \text{Suction Lift, ft} + \text{Discharge Head, ft}$$

$$= 2.27 \text{ ft} + 46.20 \text{ ft}$$

$$= 48.47 \text{ ft}$$

---

*See Conversion Tables — Section A.10, "Pressure."

Calculate the power output of the pump or water horsepower:

$$\text{Water Horsepower, HP} = \frac{(\text{Flow GPM})(\text{Head, ft})}{3960}$$

$$= \frac{(357 \text{ GPM})(48.47 \text{ ft})}{3960}$$

$$= 4.4 \text{ HP}$$

To estimate the efficiency of the pump, measure the kilowatts drawn by the pump motor. Assume the meter indicates 8000 watts or 8 kilowatts. The manufacturer claims the electric motor is 80% efficient.

$$\text{Brake Horsepower, HP} = (\text{Power to elec. motor})(\text{motor eff.})$$

$$= \frac{(8 \text{ kw})(0.80)}{0.746 \text{ kw/HP}}$$

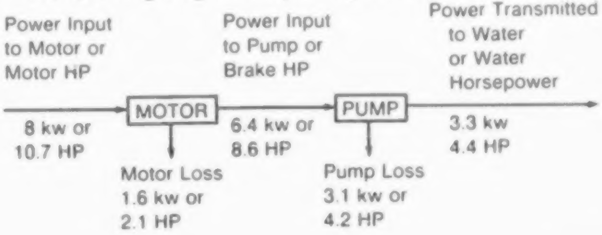
$$= 8.6 \text{ HP}$$

$$\text{Pump Efficiency, \%} = \frac{\text{Water Horsepower, HP} \times 100\%}{\text{Brake Horsepower, HP}}$$

$$= \frac{4.4 \text{ HP} \times 100\%}{8.6 \text{ HP}}$$

$$= 51\%$$

The following diagram may clarify the above problem:


Power Input to Motor or Motor HP
Power Input to Pump or Brake HP
Power Transmitted to Water or Water Horsepower
MOTOR
PUMP
8 kw or 10.7 HP
6.4 kw or 8.6 HP
3.3 kw 4.4 HP
Motor Loss 1.6 kw or 2.1 HP
Pump Loss 3.1 kw or 4.2 HP

The wire-to-water efficiency is the efficiency of the power input to produce water horsepower.

$$\begin{aligned}
\text{Wire-to-Water Efficiency, \%} &= \frac{\text{Water Horsepower, HP}}{\text{Power Input, HP}} \times 100\% \\
&= \frac{4.4\text{ HP}}{10.7\text{ HP}} \times 100\% \\
&= 41\%
\end{aligned}$$

A.87 Pump Speed — Performance Relationships

Changing the velocity of a centrigual pump will change its operating characteristics. If the speed of a pump is changed, the flow, head developed, and power requirements will change. The operating characteristics of the pump will change with speed approximately as follows:

$$\text{Flow, } Q_n = \left[\frac{N_n}{N_r}\right] Q_r$$

$$\text{Head, } H_n = \left[\frac{N_n}{N_r}\right]^2 H_r$$

$$\text{Power, } P_n = \left[\frac{N_n}{N_p}\right]^3 P_r$$

r = rated

n = now

N = pump speed

Actually, pump efficiency does vary with speed; therefore, these formulas are not quite correct. If speeds do not vary by more than a factor of two (if the speeds are not doubled or cut in half), the results are close enough. Other factors contributing to changes in pump characteristic curves include impeller wear and roughness in pipes.

Example: To illustrate these relationships, assume a pump has a rated capacity of 600 GPM, develops 100 ft of head, and has a power requirement of 15 HP when operating at 1500 rpm. If the efficiency remains constant, what will be the operating characteristics if the speed drops to 1200 rpm?

Calculate new flow rate or capacity:

$$\begin{aligned}
\text{Flow, } Q_n &= \left[\frac{N_n}{N_r}\right] Q_r \\
&= \left[\frac{1200\text{ rpm}}{1500\text{ rpm}}\right] 600\text{ GPM} \\
&= \left[\frac{4}{5}\right] 600\text{ GPM} \\
&= (4)(120\text{ GPM}) \\
&= 480\text{ GPM}
\end{aligned}$$

Calculate new head:

$$\begin{aligned}
\text{Head, } H_n &= \left[\frac{N_n}{N_r}\right]^2 H_r \\
&= \left[\frac{1200\text{ rpm}}{1500\text{ rpm}}\right]^2 100\text{ ft} \\
&= \left(\frac{4}{5}\right)^2 100\text{ ft} \\
&= \left(\frac{16}{25}\right)(100\text{ ft}) \\
&= 16\,(4\text{ ft}) \\
&= 64\text{ ft}
\end{aligned}$$

Calculate new power requirement:

$$\begin{aligned}
\text{Power, } P_n &= \left[\frac{N_n}{N_r}\right]^3 P_r \\
&= \left(\frac{1200\text{ rpm}}{1500\text{ rpm}}\right)^3 15\text{ HP} \\
&= \left(\frac{4}{5}\right)^3 15\text{ HP} \\
&= \left(\frac{64}{125}\right) 15\text{ HP} \\
&= \left(\frac{64}{25}\right)(3\text{ HP}) \\
&= 7.7\text{ HP}
\end{aligned}$$

A.88 Friction or Energy Losses

Whenever water flows through pipes, valves and fittings, energy is lost due to pipe friction (resistance), friction in valves and fittings, and the turbulence resulting from the flowing water changing its direction. Figure A.1 can be used to convert the friction losses through valves and fittings to lengths of straight pipe that would produce the same amount of friction losses. To estimate the friction or energy losses resulting from water flowing in a pipe system, we need to know:

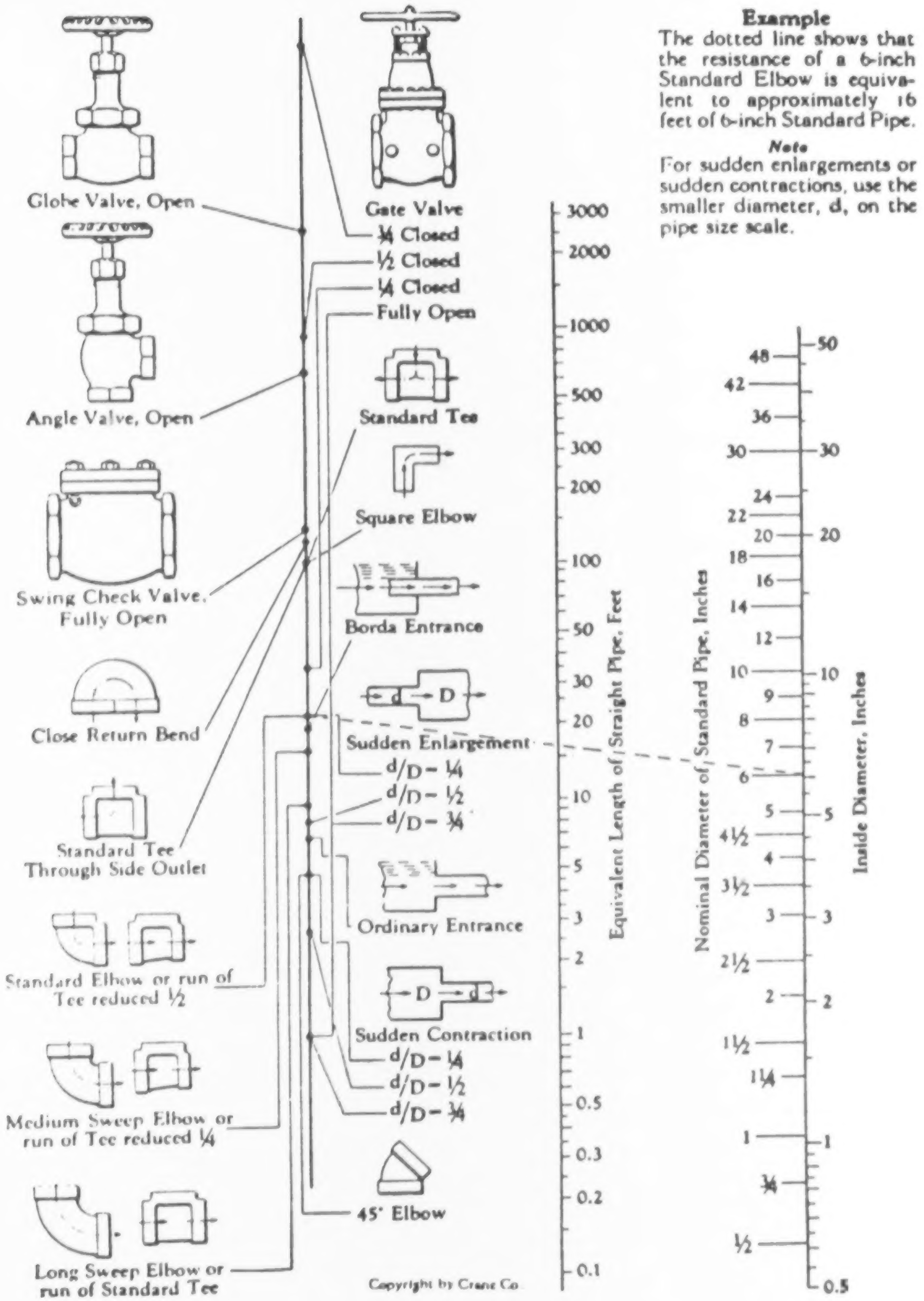
1. Water flow rate,
2. Pipe size or diameter and length, and
3. Number, size and type of valve fittings.

An easy way to estimate friction or energy losses is to follow the following steps:

1. Determine the flow rate;
2. Determine the diameter and length of pipe;
3. Convert all valves and fittings to equivalent lengths of straight pipe (see Figure A.1);
4. Add up total length of equivalent straight pipe; and
5. Estimate friction or energy losses by using Figure A.2. With the flow in GPM and diameter of pipe, find the friction loss per 100 feet of pipe. Multiply this value by equivalent length of straight pipe.

The procedure for using Figure A.1 is very easy. Locate the type of valve or fitting you wish to convert to an equivalent pipe length; find its diameter on the right-hand scale; and draw a straight line between these two points to locate the equivalent length of straight pipe.

Example: Estimate the friction losses in the piping system of a pump station when the flow is 1,000 GPM. The 8-inch suction line is 10 feet long and contains a 90-degree bend (long sweep elbow), a gate valve and an 8-inch by 6-inch reducer at the inlet to the pump. The 6-inch discharge line is 30 feet long and contains a check valve, a gate valve, and three 90-degree bends (medium sweep elbows):



Example
The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note
For sudden enlargements or sudden contractions, use the smaller diameter, d, on the pipe size scale.

Fig. A.1 Resistance of valves and fittings to flow of water

(Reprinted by permission of Crane Co.)

U.S. GPM	0.5 in.		0.75 in.		1 in.		1.25 in.		1.5 in.		2 in.		2.5 in.	
	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.
10	10.56	95.9	6.02	23.0	3.71	6.86	2.15	1.77	1.58	.83	.96	.25	.67	.11
20			12.0	86.1	7.42	25.1	4.29	6.34	3.15	2.94	1.91	.87	1.34	.36
30					11.1	54.6	6.44	13.6	4.73	6.26	2.87	1.82	2.01	.75
40					14.8	95.	8.58	23.5	6.30	10.79	3.82	3.10	2.68	1.28
50							10.7	36.0	7.88	16.4	4.78	4.67	3.35	1.94
60							12.9	51.0	9.46	23.2	5.74	6.59	4.02	2.72
70							15.0	68.8	11.03	31.3	6.69	8.86	4.69	3.63
80							17.2	89.2	12.6	40.5	7.65	11.4	5.36	4.66
90									14.2	51.0	8.60	14.2	6.03	5.82
100									15.8	62.2	9.56	17.4	6.70	7.11
120									18.9	88.3	11.5	24.7	8.04	10.0
140											13.4	33.2	9.38	13.5
160											15.3	43.0	10.7	17.4
180											17.2	54.1	12.1	21.9
200											19.1	66.3	13.4	26.7
220											21.0	80.0	14.7	32.2
240											22.9	95.0	16.1	38.1
260													17.4	44.5
280													18.8	51.3
300													20.1	58.5
350													23.5	79.2

U.S. GPM	3 in.		4 in.		5 in.		6 in.		8 in.		10 in.		12 in.		14 in.		16 in.		18 in.		20 in.	
	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.
20	.91	.15																				
40	1.82	.55	1.02	.13																		
50	2.72	1.17	1.53	.28	.96	.08																
80	3.63	2.02	2.04	.48	1.28	.14	.91	.06														
100	4.54	3.10	2.55	.73	1.60	.20	1.13	.10														
120	5.45	4.40	3.06	1.03	1.92	.29	1.36	.13														
140	6.35	5.93	3.57	1.38	2.25	.38	1.59	.18														
160	7.26	7.71	4.08	1.78	2.57	.49	1.82	.23														
180	8.17	9.73	4.60	2.24	2.89	.61	2.04	.28														
200	9.08	11.9	5.11	2.74	3.21	.74	2.27	.35														
220	9.98	14.3	5.62	3.28	3.53	.88	2.50	.42	1.40	.10												
240	10.9	17.0	6.13	3.88	3.85	1.04	2.72	.49	1.53	.12												
260	11.8	19.8	6.64	4.54	4.17	1.20	2.95	.57	1.66	.14												
280	12.7	22.8	7.15	5.25	4.49	1.38	3.18	.66	1.79	.16												
300	13.6	26.1	7.66	6.03	4.81	1.58	3.40	.75	1.91	.18												
350			8.94	8.22	5.61	2.11	3.97	1.01	2.24	.24												
400			10.20	10.7	6.41	2.72	4.54	1.30	2.55	.30												
460			11.45	13.4	7.22	3.41	5.11	1.64	2.87	.38	1.84	.12										
500			12.8	16.6	8.02	4.16	5.67	2.02	3.19	.46	2.04	.15	1.42	.06								
550			14.0	19.9	8.82	4.98	6.24	2.42	3.51	.56	2.25	.18	1.56	.07								
600					9.62	5.88	6.81	2.84	3.83	.66	2.45	.21	1.70	.08	1.25	.04						
700					11.2	7.93	7.94	3.87	4.47	.88	2.86	.29	1.99	.12	1.46	.05						
800					12.8	10.22	9.08	5.06	5.11	1.14	3.27	.37	2.27	.15	1.67	.07						
900					14.4	12.9	10.2	6.34	5.74	1.44	3.68	.46	2.55	.18	1.88	.09						
1000							11.3	7.73	6.38	1.76	4.09	.57	2.84	.22	2.08	.11						
1100							12.5	9.80	7.02	2.14	4.49	.68	3.12	.27	2.29	.13						
1200							13.6	11.2	7.66	2.53	4.90	.81	3.40	.32	2.50	.15	1.91	.08				
1300							14.7	13.0	8.30	2.94	6.31	.95	3.69	.37	2.71	.17	2.07	.09				
1400									8.93	3.40	5.72	1.09	3.97	.43	2.92	.20	2.23	.10				
1500									9.57	3.91	6.13	1.25	4.26	.49	3.13	.23	2.34	.12				
1600									10.2	4.45	6.54	1.42	4.54	.55	3.33	.25	2.55	.13	2.02	.07		
1700									10.8	5.00	6.94	1.60	4.87	.62	3.54	.29	2.71	.15	2.15	.08		
1800									11.5	5.58	7.35	1.78	5.11	.70	3.75	.32	2.87	.16	2.27	.09		
1900									12.1	6.19	7.76	1.97	5.39	.77	3.96	.35	3.03	.18	2.40	.10		
2000									12.8	6.84	8.17	2.17	5.67	.86	4.17	.39	3.19	.20	2.52	.11		
2500											10.2	3.38	7.10	1.33	5.21	.60	3.99	.31	3.15	.17		
3000											12.3	4.79	8.51	1.88	6.25	.86	4.79	.44	3.78	.24	3.06	.14
3500											14.3	6.55	9.93	2.56	7.29	1.16	5.58	.58	4.41	.32	3.57	.19
4000													11.3	3.31	8.34	1.50	6.38	.75	5.04	.42	4.08	.24
4500													12.8	4.18	9.38	1.88	7.18	.95	5.67	.53	4.59	.31
5000													14.7	5.13	10.4	2.30	7.98	1.17	6.30	.65	5.11	.38
6000															12.5	3.31	9.57	1.66	7.56	.92	6.13	.53
7000															14.6	4.50	11.2	2.26	8.83	1.24	7.15	.72
8000																	12.8	2.96	10.09	1.61	8.17	.94
9000																	14.4	3.73	11.3	2.02	9.19	1.18
10000																			12.6	2.48	10.2	1.45

No allowance has been made for age, differences in diameter, or any other abnormal condition of interior surface. Any Factor of Safety must be estimated from the local conditions and the requirements of each particular installation. For general purposes, 15% is a responsible Factor of Safety.

Fig. A.2 Friction Loss for Water in Feet Per 100 Feet of Pipe

(Reprinted from the 10th Edition of the Standards of the Hydraulic Institute, 122 East 42nd Street, New York)

SUCTION LINE (8-inch diameter)

Item	Equivalent Length, ft
1. Length of pipe	10
2. 90-degree bend	14
3. Gate valve	4
4. 8-inch by 6-inch reducer	17
5. Ordinary entrance	12
Total equivalent length	57 feet

Friction loss (Fig. A.2) = 1.76 ft/100 ft of pipe

DISCHARGE LINE (6-inch diameter)

Item	Equivalent Length, ft
1. Length of pipe	30
2. Check valve	38
3. Gate valve	4
4. Three 90-degree bends (3) (14)	42
Total equivalent length	114 feet

Friction loss (Fig. A.2) = 7.73 ft/100 ft of pipe

Estimate the total friction losses in pumping system for a flow of 1,000 GPM.

SUCTION

Loss = (1.76 ft/100 ft) (57 ft) = 1.0 Ft

DISCHARGE

Loss = (7.73 ft/100 ft)(114 ft) = 8.8 ft

Total friction losses, ft = 8.9 ft

A.9 STEPS IN SOLVING PROBLEMS

A.90 Identification of Problem

To solve any problem, you have to identify the problem, determine what kind of answer is needed, and collect the information needed to solve the problem. A good approach to this type of problem is to examine the problem and make a list of *KNOWN* and *UNKNOWN* information.

Example: Find the theoretical detention time in a rectangular sedimentation tank 8 feet deep, 30 feet wide, and 60 feet long when the flow is 1.4 MGD.

Known		Unknown
Depth	= 8 ft	Detention Time, hours
Width	= 30 ft	
Length	= 60 ft	
Flow	= 1.4 MGD	

Sometimes a drawing or sketch will help to illustrate a problem and indicate the knowns, unknowns, and possibly additional information needed.

A.91 Selection of Formula

Most problems involving mathematics in wastewater treatment plant operation can be solved by selecting the proper formula, inserting the known information, and calculating the unknown. In our example, we could look in chapter 5, "Sedimentation," or in Section A.11 of this chapter, "Basic Formulas," to find a formula for calculating detention time. From Section A.11:

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

To convert the known information to fit the terms in a formula sometimes requires extra calculations. The next step is to find the values of any terms in the formula that are not in the list of known values.

Flow, gal/day = 1.4 MGD

= 1,400,000 gal/day

From Section A.30:

$$\begin{aligned}\text{Tank Volume, cu ft} &= (\text{Length, ft})(\text{Width, ft})(\text{Height, ft})\\ &= 60\text{ ft} \times 30\text{ ft} \times 8\text{ ft}\\ &= 14{,}400\text{ cu ft}\end{aligned}$$

Solution of Problem:

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}\\ &= \frac{(14{,}400\text{ cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{1{,}400{,}000\text{ gal/day}}\\ &= 1.85\text{ hr}\end{aligned}$$

The remainder of this section discusses the details that must be considered in solving this problem.

A.92 Arrangement of Formula

Once the proper formula is selected, you may have to rearrange the terms to solve for the unknown term. From Section A.71, "Flow Rate," we can develop the formula:

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, cu ft/sec}}{\text{Cross-Sectional Area, sq ft}}$$

$$\text{or} \qquad V = \frac{Q}{A}$$

In this equation if Q and A were given the equation could be solved for V. If V and A were known, the equation would have to be rearranged to solve for Q. To move terms from one side of an equation to another, use the following rule:

When moving a term or number from one side of an equation to the other, move the numerator (top) of one side to denominator (bottom) of the other; or from the denominator (bottom) of one side to the numerator (top) of the other.

$$V = \frac{Q}{A} \text{ or } Q = AV \text{ or } A = \frac{Q}{V}$$

If the volume of a sedimentation tank and the desired detention time were given, the detention time formula could be rearranged to calculate the design flow.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

By rearranging the terms

$$\text{Flow, gal/day} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Detention Time, hrs}}$$

A.93 Unit Conversions

Each term in a formula or mathematical calculation must be of the correct units. The area of a rectangular clarifier (Area, sq ft = Length, ft × Width, ft) can't be calculated in square feet if the width is given as 246 inches or 20 feet 6 inches. The width must be converted to 20.5 feet. In the example problem, if the tank volume were given in gallons, then the 7.48 gal/cu ft would not be needed. THE UNITS IN A FORMULA MUST ALWAYS BE CHECKED BEFORE ANY CALCULATIONS ARE PERFORMED TO AVOID TIME-CONSUMING MISTAKES.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

$$= \frac{\cancel{\text{cu ft}}}{} \times \frac{\cancel{\text{gal}}}{\cancel{\text{cu ft}}} \times \frac{\text{hr}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{\cancel{\text{gal}}}$$

$$= \text{hr (all other units cancel)}$$

NOTE: We have hours = hr. One should note that the hour unit on both sides of the equation can be cancelled out and nothing would remain. This is one more check that we have the correct units. By rearranging the detention time formula, other unknowns could be determined.

If the design detention time and design flow were known, the required capacity of the tank could be calculated.

$$\text{Tank Volume, cu ft} = \frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}$$

If the tank volume and design detention time were known, the design flow could be calculated.

$$\text{Flow, gal/day} = \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Detention Time, hrs}}$$

Rearrangement of the detention time formula to find other unknowns illustrates the need to always use the correct units.

A.94 Calculations

Sections A.12, "Multiplication," and A.13, "Division," outline the steps to follow in mathematical calculations. In general, do the calculations inside parentheses ( ) first and brackets [ ] next. Calculations should be done above and below the division line before dividing.

$$\text{Detention Time, hrs} = \frac{[(\text{Tank, Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})]}{\text{Flow, gal/day}}$$

$$= \frac{[(14{,}400\ \text{cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})]}{1{,}400{,}000\ \text{gal/day}}$$

$$= \frac{2{,}585{,}088\ \text{gal-hr/day}}{1{,}400{,}000\ \text{gal/day}}$$

$$= 1.85\text{, or}$$

$$= 1.9\ \text{hr}$$

A.95 Significant Figures

In calculating the detention time in the previous section, the answer is given as 1.9 hr. The answer could have been calculated:

$$\text{Detention Time,hrs} = \frac{2{,}585{,}088\ \text{gal-hr/day}}{1{,}400{,}000\ \text{gal/day}}$$

$$= 1.846491429\ \ldots\ \text{hours}$$

How does one know when to stop dividing? Common sense and significant figures both help.

First, consider the meaning of detention time and the measurements that were taken to determine the knowns in the formula. Detention time in a tank is a theoretical value and assumes that all particles of water throughout the tank move through the tank at the same velocity. This assumption is not correct; therefore, detention time can only be a representative time for some of the water particles.

Will the flow of 1.4 MGD be constant throughout the 1.9 hours, and is the flow exactly 1.4 MGD, or could it be 1.35 MGD or 1.428 MGD? A carefully calibrated flow meter may give a reading within 2% of the actual flow rate. Flows into a tank fluctuate and flow meters do not measure flows extremely accurately; so the detention time again appears to be a representative or typical detention time.

Tank dimensions are probably satisfactory within 0.1 ft. A flow meter reading of 1.4 MGD is less precise and it could be 1.3 or 1.5 MGD. A 0.1 MGD flow meter error when the flow is 1.4 MGD is (0.1/1.4) × 100% = 7% error. A detention time of 1.9 hours, based on a flow meter reading error of plus or minus 7%, also could have the same error or more, even if the flow was constant. Therefore, the detention time error could be 1.9 hours × 0.07 = ± 0.13 hours.

In most of the calculations in the operation of water treatment plants, the operator uses measurements determined in the lab or read from charts, scales, or meters. The accuracy of every measurement depends on the sample being measured, the equipment doing the measuring, and the operator reading or measuring the results. Your estimate is no better than the least precise measurement. Do not retain more than one doubtful number.

To determine how many figures or numbers mean anything in an answer, the approach called "significant figures" is used. In the example the flow was given in two significant figures (1.4 MGD), and the tank dimensions could be considered accurate to the nearest tenth of a foot (depth = 9.0 ft) or two significant figures. Since all measurements and the constants contained two significant figures, the results should be reported as two significant figures or 1.9 hours. The calculations are normally carried out to three significant figures (1.85 hours) and rounded off to two significant figures (1.9 hours).

Decimal points require special attention when determining the number of significant figures in a measurement.

Measurement	**Significant Figures**
0.00325	3
11.078	5
21,000.	2

Example: The distance between two points was divided into three sections, and each section was measured by a different group. What is the distance between the two points if each group reported the distance if measured as follows:

Group	**Distance, ft**	**Significant Figures**
A	11,300.	3
B	2,438.9	5
C	87.62	4
Total Distance	13,826.52	

Group A reported the length of the section it measured to three significant figures; therefore, the distance between the two points should be reported as 13,800 feet (3 significant figures).

When adding, substracting, multiplying, or dividing, the number of significant figures in the answer should not be more than the term in the calculations with the least number of significant figures.

A.96 Check Your Results

After having completed your calculations, you should carefully examine your calculations and answer. Does the answer seem reasonable? If possible, have another operator check your calculations before making any operational changes.

A.10 BASIC CONVERSION FACTORS (ENGLISH SYSTEM)

UNITS		
1,000,000	= 1 Million	1,000,000/1 Million
LENGTH		
12 in	= 1 ft	12 in/ft
3 ft	= 1 yd	3 ft/yd
5280 ft	= 1 mi	5280 ft/mi
AREA		
144 sq in	= 1 sq ft	144 sq in/sq ft
43,560 sq ft	= 1 acre	43,560 sq ft/ac
VOLUME		
7.48 gal	= 1 cu ft	7.48 gal/cu ft
1000 m*L*	= 1 liter	1000 m*L*/*L*
3.785 *L*	= 1 gal	3.785 *L*/gal
231 cu in	= 1 gal	231 cu in/gal
WEIGHT		
1000 mg	= 1 gm	1000 mg/gm
1000 gm	= 1 kg	1000 gm/kg
454 gm	= 1 lb	454 gm/lb
2.2 lbs	= 1 kg	2.2 lbs/kg
POWER		
0.746 kw	= 1 HP	0.746 kw/HP
DENSITY		
8.34 lbs	= 1 gal	8.34 lbs/gal
62.4 lbs	= 1 cu ft	62.4 lbs/cu ft
DOSAGE		
17.1 mg/*L*	= 1 grain/gal	17.1 mg/*L*/gpg
64.7 grains	= 1 mg	64.7 grains/mg
PRESSURE		
2.31 ft water	= 1 psi	2.31 ft water/psi
0.433 psi	= 1 ft water	0.433 psi/ft water
1.133 ft water	= 1 in Mercury	1.133 ft water/in Mercury
FLOW		
694 GPM	= 1 MGD	694 GPM/MGD
1.55 CFS	= 1 MGD	1.55 CFS/MGD
TIME		
60 sec	= 1 min	60 sec/min
60 min	= 1 hr	60 min/hr
24 hr	= 1 day	24 hr/day

A.11 BASIC FORMULAS

FLOWS

1. $$\text{Flow, MGD} = \frac{(\text{Flow, GPM})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000/\text{M}}$$

or $$\text{Flow, GPM} = \frac{(\text{Flow, MGD})(1{,}000{,}000/\text{M})}{(60\text{ min/hr})(24\text{ hr/day})}$$

or $$\text{Flow, cfs} = \frac{(\text{Flow, MGD})(1{,}000{,}000/\text{M})}{(7.48\text{ gal/cu ft})(24\text{ hr/day})(60\text{ min/hr})(60\text{ sec/min})}$$

$$= (\text{Flow, MGD})(1.55\text{ cfs/MGD})$$

GRIT CHANNELS

2. $$\text{Velocity, ft/sec} = \frac{\text{Distance Traveled, ft}}{\text{Time, sec}}$$

or $$\text{Velocity, ft/sec} = \frac{\text{Flow, cfs}}{\text{Area, sq ft}}$$

3. $$\text{Grit Removed, cu ft/MG} = \frac{\text{Volume of Grit, cu ft}}{\text{Volume of Flow, MG}}$$

SEDIMENTATION TANKS AND CLARIFIERS

4. $$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

5. $$\text{Surface Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

6. $$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Length of Weir, ft}}$$

7. $$\text{Solids Loading, lb/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

where

$$\text{Solids Applied, lbs/day} = (\text{Flow, MGD})(\text{Solids, mg}/L)(8.34\text{ lbs/gal})$$

TRICKLING FILTERS

8. $$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

9. $$\text{Organic Loading, lbs BOD/day/1000 cu ft} = \frac{\text{BOD Applied, lbs/day}}{\text{Volume of Media, 1000 cu ft}}$$

where

$$\text{BOD Applied, lbs/day} = (\text{Flow, MGD})(\text{BOD, mg}/L)(8.34\text{ lbs/gal})$$

10. $$\text{Plant Efficiency, \%} = \left(\frac{\text{In-Out}}{\text{In}}\right)(100\%)$$

ROTATING BIOLOGICAL CONTACTORS

11. $$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

12. $$\text{Organic Loading, lbs BOD/day/1000 sq ft} = \frac{\text{Soluble BOD Applied, lbs/day}}{\text{Surface Area of Media, 1000 sq ft}}$$

where

$$\text{Soluble BOD, mg}/L = \text{Total BOD, mg}/L - (\text{K})(\text{Suspended Solids, mg}/L)$$

ACTIVATED SLUDGE

13. $$\text{Sludge Volume Index or SVI} = \frac{(\text{Settleable Solids, \%})(10{,}000)}{\text{MLSS, mg}/L}$$

14. $$\text{Aerator Solids, lbs} = (\text{Tank Vol, MG})(\text{MLSS, mg}/L)(8.34\text{ lbs/gal})$$

15. $$\text{Aerator Loading, lbs BOD/day} = (\text{Flow, MGD})(\text{Pri Eff BOD, mg}/L)(8.34\text{ lbs/gal})$$

478

16.
$$\text{Sludge Age, days} = \frac{\text{Aerator or Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs/day}}$$
$$= \frac{\text{(Tank Vol, MG)(MLSS, mg/}L\text{)(8.34 lbs/gal)}}{\text{(Flow, MGD)(Pri Eff SS, mg/}L\text{)(8.34 lbs/gal)}}$$

PONDS

17.
$$\text{Detention Time, days} = \frac{\text{Pond Volume, ac-ft}}{\text{Flow Rate, ac-ft/day}}$$

where

$$\text{Pond Area, acres} = \frac{\text{(Average Width, ft)(Average Length, ft)}}{\text{43,560 sq ft/acre}}$$

$$\text{Pond Volume, ac ft} = \text{(Area, ac)(Depth, ft)}$$

$$\text{Flow Rate, ac-ft/day} = \frac{\text{Flow, gal/day}}{\text{(7.48 gal/cu ft)(43,560 sq ft)}}$$

18.
$$\text{Population Loading, person/ac} = \frac{\text{Population Served, persons}}{\text{Pond Surface Area, acres}}$$

19.
$$\text{Hydraulic Loading, inches/day} = \frac{\text{Depth of Pond, inches}}{\text{Detention Time, days}}$$

20.
$$\text{Organic Loading, lbs BOD/day/ac} = \frac{\text{(Flow, MGD)(BOD, mg/}L\text{)(8.34 lbs/day)}}{\text{Area, acres}}$$

CHLORINATION

21.
$$\text{Chlorine Demand, mg/}L \quad \text{Chlorine Dose, mg/}L - \text{Chlorine Residual, mg/}L$$

22.
$$\text{Chlorine Feed Rate, lbs/day} = \text{(Flow MGD)(Dose, mg/}L\text{)(8.34 lbs/gal)}$$

CHEMICAL DOSES

Chemical Feeder Setting

23.
$$\text{Chemical Dose, lbs/day} = \text{(Flow, MGD)(Dose, mg/}L\text{)(8.34 lbs/gal)}$$

24.
$$\text{Chemical Feeder Setting, m}L\text{/min} = \frac{\text{(Flow, MGD)(Alum Dose, mg/}L\text{)(3.785 }L\text{/gal)(1,000,000)}}{\text{(Liquid Alum, mg/m}L\text{)(24 hr/day)(60 min/hr)(1 Million)}}$$

25.
$$\text{Chemical Feeder Setting, gal/day} = \frac{\text{(Flow, MGD)(Alum Dose, mg/}L\text{)(8.34 lbs/gal)}}{\text{Liquid Alum, lbs/gal}}$$

Calibration of a Dry Chemical Feeder

26.
$$\text{Chemical Feed, lbs/day} = \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$$

Calibration of a Solution Chemical Feeder
(Chemical Feed Pump or a Hypochlorinator)

27.
$$\text{Chemical Feed, lbs/day} = \frac{\text{(Chem Conc, mg/}L\text{)(Vol Pumped, m}L\text{)(60 min/hr)(24 hr/day)}}{\text{(Time Pumped, min)(1000 m}L/L\text{)(1000 mg/gm)(454 gm/lb)}}$$

28.
$$\text{Chemical Feed, GPM} = \frac{\text{Chemical Used, gal}}{\text{(Time, hr)(60 min/hr)}}$$
$$\text{or} = \frac{\text{(Chemical Feed Rate, m}L\text{/sec)(60 sec/min)}}{\text{3785 m}L\text{/gal}}$$

29a.
$$\text{Chemical Solution, gal} = \frac{\text{(Chemical Solution, \%)(8.34 lbs/gal)}}{\text{100\%}}$$

29b.
$$\text{Feed Pump, GPD} = \frac{\text{Chemical Feed, lbs/day}}{\text{Chemical Solution, lbs/gal}}$$

29c.
$$\text{Feeder Setting, \%} = \frac{\text{(Desired Feed Pump, GPD)(100\%)}}{\text{Maximum Feed Pump, GPD}}$$

A.12 HOW TO USE THE BASIC FORMULAS

One clever way of using the basic formulas is to use the Davidson[1] Pie Method. To apply this method to the first basic formula,

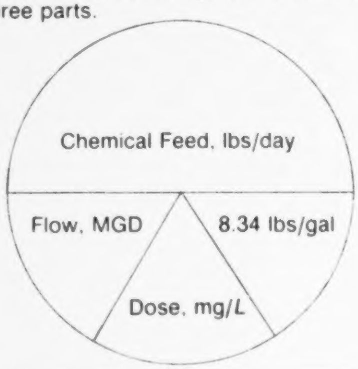
1.
$$\text{Chemical Feeder, lbs/day} = \text{(Flow, MGD)(Dose,mg/}L\text{)(8.34 lbs/gal)}$$

(a) Draw a circle and draw a horizontal line through the middle of the circle;

(b) Write the Chemical Feed, lbs/day in the top half;

(c) Divide the bottom half into three parts; and

(d) Write Flow, MGD; Dose, mg/*L*, and 8.34 lbs/gal in the other three parts.



If you want to find the Chemical Feed, lbs/day, cover up the Chemical Feed, and what is left uncovered will give you the correct formula.

2.
$$\text{Chemical Feed, lbs/day} = \text{(Flow, MGD)(Dose, mg/}L\text{)(8.34 lbs/gal)}$$

If you know the chlorinator setting in pounds per day and the flow in MGD and would like to know the dose in mg/*L*, cover up the Dose, mg/*L*, and what is left uncovered will give you the correct formula.

3.
$$\text{Dose, mg/}L = \frac{\text{Chemical Feed, lbs/day}}{\text{(Flow, MGD)(8.34 lbs/gal)}}$$

Another approach to using the basic formulas is to memorize the basic formula, for example the detention time formula.

4.
$$\text{Detention Time, hr} = \frac{\text{(Tank Volume, gal)(24 hr/day)}}{\text{Flow, gal/day}}$$

This formula works fine to solve for the detention time when the Tank Volume, gal, and Flow, gal/day, are given.

If you wish to determine the Flow, gal/day, when the Detention Time, hr, and Tank Volume, gal, are given, you must change the basic formula. You want the Flow, gal/day, on the left of the equal sign and everything else on the right of the equal sign. This is done by moving the terms diagonally (from top to bottom or from bottom to top) past the equal sign.

---

[1] Gerald Davidson, Manager, Clear Lake Oaks Water District, Clear Lake Oaks, California.

$$4.\ \text{Detention Time, hr} = \frac{(\text{Tank Volume, gal})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

or

$$\text{Flow, gal/day} = \frac{(\text{Tank Volume, gal})(24\ \text{hr/day})}{\text{Detention Time, hr}}$$

This same approach can be used if the Tank Volume, gal, was unknown and the Detention Time, hr, and Flow, gal/day, were given. We want Tank Volume, gal, on one side of the equation and everything else on the other side.

$$4.\ \text{Detention Time, hr} = \frac{(\text{Tank Volume, gal})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

To Top

To Bottom

or

$$\frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{24\ \text{hr/day}} = \text{Tank Volume, gal}$$

or

$$\text{Tank Volume, gal} = \frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{24\ \text{hr/day}}$$

One more check is to be sure the units in the rearranged formula cancel out correctly.

For additional information on the use of the basic formulas, refer to Sections:

A.91, "Selection of Formula,"

A.92, "Arrangement of Formula,"

A.93, "Unit Conversions," and

A.94, "Calculations."

A.13 TYPICAL WASTEWATER PLANT PROBLEMS (ENGLISH SYSTEM)

A.130 Flows

EXAMPLE 1

Convert a flow of 600 gallons per minute to million gallons per day.

Known	Unknown
Flow, GPM = 600 GPM	Flow, MGD

Convert flow from 600 GPM to MGD.

$$\begin{aligned}\text{Flow, MGD} &= \frac{(\text{Flow, GPM})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000/\text{M}}\\ &= \frac{(600\ \text{GPM})(60\ \text{min/hr})(24\ \text{hr/day})}{1{,}000{,}000/\text{M}}\\ &= 0.86\ \text{MGD}\end{aligned}$$

NOTE: When we divide by 1,000,000/M this is just like dividing an equation by 12 inches/foot or 60 minutes/hour; all we are doing is changing units.

EXAMPLE 1a

Convert a flow from 1.2 MGD to cubic feet per second.

Known	Unknown
Flow, MGD = 1.2 MGD	Flow, cfs

Convert a flow from 1.2 MGD to cfs.

$$\begin{aligned}\text{Flow, cfs} &= \frac{(\text{Flow, MGD})(1{,}000{,}000/\text{M})}{(7.48\ \text{gal/cu ft})(24\ \text{hr/day})(60\ \text{min/hr})(60\ \text{sec/min})}\\ &= \frac{(1.2\ \text{MGD})(1{,}000{,}000/\text{M})}{(7.48\ \text{gal/cu ft})(24\ \text{hr/day})(60\ \text{min/hr})(60\ \text{sec/min})}\\ &= 1.86\ \text{cfs}\end{aligned}$$

or

$$\begin{aligned}\text{Flow, cfs} &= (\text{Flow, MGD})(1.55\ \text{cfs/MGD})\\ &= (1.2\ \text{MGD})(1.55\ \text{cfs/MGD})\\ &= 1.86\ \text{cfs}\end{aligned}$$

A.131 Grit Channels

EXAMPLE 2

Estimate the velocity of wastewater flowing through a grit channel if a stick travels 32 feet in 36 seconds.

Known	Unknown
Distance = 32 ft	Velocity, ft/sec
Time = 36 sec	

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Distance Traveled, ft}}{\text{Time, sec}}\\ &= \frac{32\ \text{ft}}{36\ \text{sec}}\\ &= 0.89\ \text{ft/sec}\end{aligned}$$

EXAMPLE 3

A grit channel removed 3.2 cu ft of grit during a period when the total flow was 0.8 MG. How many cu ft of grit are removed per MG?

Known	Unknown
Vol of Grit = 3.2 cu ft	Grit Removed, cu ft/MG
Vol of Flow = 0.8 MG	

$$\begin{aligned}\text{Grit Removed, cu ft/MG} &= \frac{\text{Volume of Grit, cu ft}}{\text{Volume of Flow, MG}}\\ &= \frac{3.2\ \text{cu ft}}{0.8\ \text{MG}}\\ &= 4.0\ \text{cu ft/MG}\end{aligned}$$

132. Sedimentation Tanks And Clarifiers

EXAMPLES 4, 5, 6 and 7

A circular secondary clarifier handles a flow of 0.9 MGD and a suspended solids of 3600 mg/*L*. The clarifier is 50 feet in diameter and 8 feet deep. Find the detention time, surface loading rate, and weir overflow rate.

Known	Unknown
Flow = 0.9 MGD	4. Detention Time, hours
Diameter = 50 ft	5. Surface Loading, gpd/sq ft

Depth = 8 ft	6. Weir Overflow, gpd/ft
SS, mg/L = $3600\ \text{mg}/L$	7. Solids Loading, lbs/day/sq ft

4. *DETENTION TIME*

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.5\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

$$\text{Tank Volume, cu ft} = (\text{Area, sq ft})(\text{Depth, ft})$$

$$\begin{aligned}\text{Clarifier Area, sq ft} &= 0.785(\text{Diameter, ft})^2\\ &= 0.785(50\ \text{ft})^2\\ &= 1962.5\ \text{sq ft, or}\\ &= 1960\ \text{sq ft}\end{aligned}$$

$$\begin{aligned}\text{Tank Volume, cu ft} &= (\text{Area, sq ft})(\text{Depth, ft})\\ &= (1960\ \text{sq ft})(8\ \text{ft})\\ &= 15{,}680\ \text{cu ft}\end{aligned}$$

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{(\text{Tank Volume, cu ft})(7.5\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Flow, gal/day}}\\ &= \frac{(15{,}680\ \text{cu ft})(7.5\ \text{gal/cu ft})(24\ \text{hr/day})}{900{,}000\ \text{gal/day}}\\ &= \frac{2{,}820{,}000}{900{,}000}\\ &= 3.1\ \text{hr}\end{aligned}$$

5. *SURFACE LOADING RATE*

$$\begin{aligned}\text{Surface Loading, gpd/sq ft} &= \frac{\text{Flow, gpd}}{\text{Area, sq ft}}\\ &= \frac{900{,}000\ \text{gpd}}{1960\ \text{sq ft}}\\ &= 459\ \text{gpd/sq ft}\end{aligned}$$

6. *WEIR OVERFLOW RATE*

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Length of Weir, ft}}$$

$$\begin{aligned}\text{Length of Weir, ft} &= 3.14(\text{Diameter, ft})\\ &= 3.14(50\ \text{ft})\\ &= 157\ \text{ft}\end{aligned}$$

$$\begin{aligned}\text{Weir Overflow, gpd/ft} &= \frac{\text{Flow, gpd}}{\text{Length of Weir, ft}}\\ &= \frac{900{,}000\ \text{gpd}}{157\ \text{ft}}\\ &= 5730\ \text{gpd/ft}\end{aligned}$$

7. *SOLIDS LOADING*

$$\begin{aligned}\text{Solids Applied, lbs/day} &= (\text{Flow, MGD})(\text{SS, mg}/L)(8.34\ \text{lbs/gal})\\ &= (0.9\ \text{MGD})(3600\ \text{mg}/L)(8.34\ \text{lbs/gal})\\ &= 27{,}022\ \text{lbs/day}\end{aligned}$$

$$\begin{aligned}\text{Solids Loading, lbs/day/sq ft} &= \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}\\ &= \frac{27{,}022\ \text{lbs/day}}{1{,}960\ \text{sq ft}}\\ &= 14\ \text{lbs/day/sq ft}\end{aligned}$$

A.133 Trickling Filters

EXAMPLES 8 and 9

A flow of 1.1 MGD is applied to a 50-ft diameter trickling filter which is 4 feet deep. The BOD of the wastewater is 120 mg/L. Calculate the hydraulic and organic loadings on the filter.

Known	Unknown
Flow = 1.1 MGD	8. Hydraulic Loading, gpd/sq ft
Diameter = 50 ft	
Depth = 4 ft	9. Organic Loading, $\frac{\text{lbs BOD/day}}{\text{1000 cu ft}}$
BOD = 120 mg/L	

8. *HYDRAULIC LOADING*

$$\text{Hydraulic Loading, gpd, sq ft} = \frac{\text{Flow, gpd/sq ft}}{\text{Surface Area, sq ft}}$$

$$\begin{aligned}\text{Surface Area, sq ft} &= 0.785(\text{Diameter, ft})^2\\ &= 0.785(50\ \text{ft})^2\\ &= 1960\ \text{sq ft}\end{aligned}$$

$$\begin{aligned}\text{Hydraulic Loading, gpd/sq ft} &= \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}\\ &= \frac{1{,}100{,}000\ \text{gpd}}{1960\ \text{sq ft}}\\ &= 561\ \text{gpd/sq ft}\end{aligned}$$

9. *ORGANIC LOADING*

$$\text{Organic Loading, }\frac{\text{lbs BOD/day}}{\text{1000 cu ft}} = \frac{\text{BOD Applied, lbs/day}}{\text{Volume of Media, 1000 cu ft}}$$

$$\text{BOD Applied, lbs/day} = (\text{BOD, mg}/L)(\text{Flow, MGD})(8.34\ \text{lbs/gal})$$

$$\text{Volume of Media, 1000 cu ft} = (\text{Surface Area, sq ft})(\text{Depth, ft})$$

$$\begin{aligned}\text{BOD Applied, lbs/day} &= (\text{BOD, mg}/L)(\text{Flow, MGD})(8.34\ \text{lb/gal})\\ &= (120\ \text{mg}/L)(1.1\ \text{MGD})(8.34\ \text{lb/gal})\\ &= 1100\ \text{lbs BOD/day}\end{aligned}$$

$$\begin{aligned}\text{Volume of Media, 1000 cu ft} &= (\text{Surface Area, sq ft})(\text{Depth, ft})\\ &= (1960\ \text{sq ft})(4\ \text{ft})\\ &= 7840\ \text{cu ft}\\ &= 7.84\ (1000\ \text{cu ft})\end{aligned}$$

$$\begin{aligned}\text{Organic Loading, }\frac{\text{lbs BOD/day}}{\text{1000 cu ft}} &= \frac{\text{BOD Applied, lbs/day}}{\text{Volume of Media, 1000 cu ft}}\\ &= \frac{1100\ \text{lbs BOD/day}}{7.84(1000\ \text{cu ft})}\\ &= 140\ \text{lbs BOD/day/1000 cu ft}\end{aligned}$$

EXAMPLE 10

The influent BOD to a trickling filter plant is 200 mg/*L* and the effluent BOD is 20 mg/*L*. What is the BOD removal efficiency of the plant?

Known	Unknown
Influent BOD = 200 mg/*L*	Plant Efficiency, %
Effluent BOD = 20 mg/*L*	

$$\text{Efficiency, \%} = \left(\frac{\text{In-Out}}{\text{In}}\right)(100\%)$$

$$= \left(\frac{200\text{ mg}/L - 20\text{ mg}/L}{200\text{ mg}/L}\right)(100\%)$$

$$= \frac{180\text{ mg}/L}{200\text{ mg}/L}(100\%)$$

$$= 90\%$$

A.134 Rotating Biological Contactors

EXAMPLES 11 and 12

A rotating biological contactor treats a flow of 2.4 MGD. The surface area of the media is 720,000 square feet. The influent has a total BOD of 220 mg/*L* and suspended solids of 240 mg/*L*. Assume a K value of 0.5 to calculate the soluble BOD. Calculate the hydraulic loading in gallons per day per square foot and the organic loading in pounds of soluble BOD per day per 1000 square feet of media surface.

Known		Unknown
Flow	= 2.4 MGD	11. Hydraulic Loading, gpd/sq ft
Area	= 720,000 sq ft	
Total BOD	= 220 mg/*L*	12. Organic Loading, lbs BOD/day/1000 sq ft
SS	= 240 mg/*L*	
K	= 0.5	

11. *HYDRAULIC LOADING*

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{2{,}400{,}000\text{ gpd}}{720{,}000\text{ sq ft}}$$

$$= 3.3\text{ gpd/sq ft}$$

12. *ORGANIC LOADING*

$$\text{Soluble BOD, mg}/L = \text{Total BOD, mg}/L - (\text{K})(\text{Suspended Solids, mg}/L)$$

$$= 220\text{ mg}/L - (0.5)(240\text{ mg}/L)$$

$$= 100\text{ mg}/L$$

$$\text{BOD Applied, lbs/day} = (\text{Flow, MGD})(\text{BOD, mg}/L)(8.34\text{ lbs/gal})$$

$$= (2.4\text{ MGD})(100\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 2002\text{ lbs/day}$$

$$\text{Organic Loading, lbs BOD/day/1000 sq ft} = \frac{\text{Soluble BOD Applied, lbs/day}}{\text{Surface Area of Media, 1000 sq ft}}$$

$$= \frac{2002\text{ lbs BOD/day}}{720 \cdot 1000\text{ sq ft}}$$

$$= 2.8\text{ lbs BOD/day/1000 sq ft}$$

A.135 Activated Sludge

EXAMPLES 13, 14, 15 and 16

Lab results and flow rate for an activated sludge plant are listed below under the known column. Information helpful to the operator in controlling the process is listed in the unknown column. The aerator or aeration tank volume is 0.50 MG.

Known

Mixed Liquor Suspended Solids (MLSS)	= 1800 mg/*L*
Mixed Liquor Volatile Content	= 76%
Thirty-Minute Settleable Solids Test*	= 340 m*L*, or 17%
Primary Effluent BOD	= 140 mg/*L*
Primary Effluent Suspended Solids	= 110 mg/*L*
Flow Rate	= 2.0 MGD

Unknown

13. Sludge Volume Index, SVI
14. Pounds of Solids in the Aerator
15. Pounds of BOD per Day Applied to Aerator
16. Sludge Age, days

13. *SLUDGE VOLUME INDEX*

$$\text{SVI} = \frac{(\text{Settleable Solids, \%})(10{,}000)}{\text{MLSS, mg}/L}$$

$$= \frac{(17)(10{,}000)}{1800}$$

$$= 94$$

14. *POUNDS OF SOLIDS IN AERATOR*

$$\text{Aerator Solids, lbs} = (\text{MLSS, mg}/L)(\text{Tank Vol., MG})(8.34\text{ lbs/gal})$$

$$= (1800\text{ mg}/L)(0.50\text{ MG})(8.34\text{ lbs/gal})$$

$$= 7500\text{ lbs}$$

15. *POUNDS OF BOD APPLIED PER DAY TO AERATOR*

$$\text{Aerator Loading, lbs BOD/day} = (\text{Primary Effluent BOD, mg}/L)(\text{Flow, MGD})(8.34\text{ lbs/gal})$$

$$= (140\text{ mg}/L)(2.0\text{ MGD})(8.34\text{ lbs/gal})$$

$$= 2335\text{ lbs BOD/day Applied to Aerator}$$

16. *SLUDGE AGE*

Chapter 11, "Activated Sludge," and Chapter 16, "Laboratory Procedures and Chemistry," discuss the different methods of calculating sludge age and the meaning of the results.

$$\text{Sludge Age, days} = \frac{(\text{MLSS, mg}/L)(\text{Tank Volume, MG})(8.34\text{ lb/gal})}{(\text{SS in Primary Effl., mg}/L)(\text{Flow, MGD})(8.34\text{ lbs/gal})}$$

$$= \frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs/day}}\ \text{(or Aerator Solids, lbs)}$$

$$= \frac{7500\text{ lbs}}{(110\text{ mg}/L)(2.0\text{ MGD})(8.34\text{ lb/gal})}$$

$$= \frac{7500\text{ lbs}}{1834\text{ lbs/day}}$$

$$= 4.1\text{ days}$$

---

* Thirty-minute results obtained from 60-minute settleable solids test using 2 liter cylinder.

A.136 Ponds

EXAMPLES 17, 18, 19 and 20

To calculate the different loadings on a pond, the information listed under known must be available.

Known

Avg. Depth = 4 ft
Avg. Width = 400 ft
Avg. Length = 600 ft
Flow = 0.5 MGD
BOD = 150 mg/*L*
Population = 5000 persons

Unknown

17. Detention Time, days
18. Population Loading, persons/acre
19. Hydraulic Load, in/day
20. Organic Load, lbs BOD/day/acre

17. *DETENTION TIME*

$$\text{Detention Time, days} = \frac{\text{Pond Volume, ac-ft}}{\text{Flow Rate, ac-ft/day}}$$

$$\text{Pond Area, acres} = \frac{(\text{Average Width, ft})(\text{Average Length, ft})}{43{,}560 \text{ sq ft/acre}}$$

$$= \frac{(400 \text{ ft})\ (600 \text{ ft})}{43{,}560 \text{ sq ft/acre}}$$

$$= 5.51 \text{ acres}$$

$$\text{Pond Volume, ac-ft} = (\text{Area, ac})(\text{Depth, ft})$$

$$= (5.51 \text{ acres})(4 \text{ ft})$$

$$= 22.0 \text{ ac-ft}$$

$$\text{Flow Rate, ac-ft/day} = \frac{(500{,}000 \text{ gal/day})}{(7.48 \text{ gal/cu ft})(43{,}560 \text{ sq ft/ac})}$$

$$= 1.53 \text{ ac-ft-day}$$

$$\text{Detention Time, days} = \frac{\text{Pond Volume, ac/ft}}{\text{Flow Rate, ac-ft/day}}$$

$$= \frac{22.0 \text{ ac-ft}}{1.53 \text{ ac-ft/day}}$$

$$= 14.3 \text{ days}$$

18. *POPULATION LOADING*

$$\text{Population Loading, persons/ac} = \frac{\text{Population Served, persons}}{\text{Pond Area, acres}}$$

$$= \frac{5000 \text{ persons}}{5.51 \text{ acres}}$$

$$= 907 \text{ persons/acre}$$

19. *HYDRAULIC LOADING*

$$\text{Hydraulic Loading, in/day} = \frac{\text{Depth of Pond, inches}}{\text{Detention Time, days}}$$

$$= \frac{(4 \text{ ft})(12 \text{ in/ft})}{14.3 \text{ days}}$$

$$= 3.36 \text{ in/day}$$

20. *ORGANIC LOADING*

$$\text{Organic Loading, lb BOD/day/ac} = \frac{(\text{BOD, mg}/L)(\text{Flow, MGD})(8.34 \text{ lb/gal})}{\text{Area, ac}}$$

$$= \frac{(150 \text{ mg}/L)(0.5 \text{ MGD})(8.34 \text{ lb/gal})}{5.51 \text{ ac}}$$

$$= \frac{625.5 \text{ lb BOD/day}}{5.51 \text{ ac}}$$

$$= 114 \text{ lb BOD/day/ac}$$

A.137 Chlorination

EXAMPLE 21

Determine the chlorine demand* of an effluent if the chlorine dose is 10.0 mg/*L* and the chlorine residual is 1.1 mg/*L*.

Known	Unknown
Chlorine dose = 10.0 mg/*L*	Chlorine Demand, mg/*L*
Chlorine Residual = 1.1 mg/*L*	

$$\text{Chlorine Demand, mg}/L = \text{Chlor. Dose, mg}/L - \text{Chlor. Residual, mg}/L$$

$$= 10.0 \text{ mg}/L - 1.1 \text{ mg}/L$$

$$= 8.9 \text{ mg}/L$$

EXAMPLE 22

To maintain a satisfactory chlorine residual in a plant effluent, the chlorine dose must be 10 mg/*L* when the flow is 0.37 MGD. Determine the chlorinator setting (feed rate) in pounds per day.

Known	Unknown
Dose = 10 mg/*L*	Chlorinator Setting, lbs/day
Flow = 0.37 MGD	

$$\text{Chlorine Feed Rate, lbs/day} = (\text{Dose, mg}/L)(\text{Flow, MGD})(8.34 \text{ lb/gal})$$

$$= (10 \text{ mg}/L)(0.37 \text{ MGD})(8.34 \text{ lb/gal})$$

$$= 30.9, \text{ or}$$

$$= 31 \text{ lbs/day}$$

A.138 Chemical Doses

EXAMPLE 23

Determine the chlorinator setting in pounds per 24 hours to treat a flow of 2 MGD with a chlorine dose of 3.0 mg/*L*.

Known	Unknown
Flow, MGD = 2 MGD	Chlorinator Setting, lbs/24 hours
Chlorine Dose, mg/*L* = 3.0 mg/*L*	

Determine the chlorinator setting in pounds per 24 hours or pounds per day.

$$\text{Chemical Feed, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34 \text{ lbs/gal})$$

$$= (2 \text{ MGD})(3.0 \text{ mg}/L)(8.34 \text{ lbs/gal})$$

$$= 50 \text{ lbs/day}$$

---

* *"Standard Methods" uses the term 'chlorine demand' when referring to stabilized water such as a domestic water supply and the term 'chlorination requirement' when referring to wastewater.*

EXAMPLE 24

The optimum liquid polymer dose from the jar tests is 12 mg/*L*. Determine the setting on the liquid polymer chemical feeder in milliliters per minute when the plant flow is 4.7 MGD. The liquid polymer delivered to the plant contains 642.3 milligrams of polymer per milliliter of liquid solution.

Known

Polymer Dose, mg/*L* = 12 mg/*L*
Flow, MGD = 4.7 MGD
Liquid Polymer, mg/m*L* = 642.3 mg/m*L*

Unknown

Chemical Feeder Setting, mg/m*L*

Calculate the liquid polymer chemical feeder setting in milliliters per minute.

$$\text{Chemical Feeder Setting, m}L\text{/min} = \frac{(\text{Flow, MGD})(\text{Polymer Dose, mg}/L)(3.785\ L/\text{gal})(1{,}000{,}000)}{(\text{Liquid Polymer, mg/m}L)(24\ \text{hr/day})(60\ \text{min/hr})(1\ \text{Million})}$$

$$= \frac{(4.7\ \text{MGD})(12\ \text{mg}/L)(3.785\ L/\text{gal})(1{,}000{,}000)}{(642.3\ \text{mg/m}L)(24\ \text{hr/day})(60\ \text{min/hr})(1\ \text{Million})}$$

$$= 231\ \text{m}L/\text{min}$$

EXAMPLE 25

The optimum liquid polymer dose from the jar tests is 12 mg/*L*. Determine the setting on the liquid polymer chemical feeder in gallons per day when the flow is 4.7 MGD. The liquid polymer delivered to the plant contains 5.36 pounds of polymer per gallon of liquid solution.

Known

Polymer Dose, mg/*L* = 12 mg/*L*
Flow, MGD = 4.7 MGD
Liquid Polymer lbs/gal = 5.36 lbs/gal

Unknown

Chemical Feeder Setting, GPM

Calculate the liquid polymer chemical feeder setting in gallons per day.

$$\text{Chemical Feeder Setting, GPD} = \frac{(\text{Flow, MGD})(\text{Polymer Dose, mg}/L)(8.34\ \text{lbs/gal})}{\text{Liquid Polymer, lbs/gal}}$$

$$= \frac{(4.7\ \text{MGD})(12\ \text{mg}/L)(8.34\ \text{lbs/gal})}{5.36\ \text{lbs/gal}}$$

$$= 88\ \text{GPD}$$

EXAMPLE 26

Determine the actual chemical feed in pounds per day from a dry chemical feeder. A bucket placed under the chemical feeder weighed 0.3 pounds empty and 2.1 pounds after 30 minutes.

Known

Empty Bucket, lbs = 0.3 lbs
Full Bucket, lbs = 2.1 lbs
Time to Fill, min = 30 min

Unknown

Chemical Feed, lbs/day

Determine the chemical feed in pounds of chemical applied per day.

$$\text{Chemical Feed, lbs} = \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$$

$$= \frac{(2.1\ \text{lbs} - 0.3\ \text{lbs})(60\ \text{min/hr})(24\ \text{hr/day})}{(30\ \text{min})}$$

$$= 86\ \text{lbs/day}$$

EXAMPLE 27

Determine the chemical feed in pounds of polymer per day from a chemical feed pump. The polymer solution is 1.5 percent or 15,000 mg polymer per liter. Assume a specific gravity of the polymer solution of 1.0. During a test run the chemical feed pump delivered 800 m*L* of polymer solution during five minutes.

Known

Polymer Solution, % = 1.5%
Polymer Conc, mg/*L* = 15,000 mg/*L*
Polymer Sp Gr = 1.0
Volume Pumped, m*L* = 800 m*L*
Time Pumped, min = 5 min

Unknown

Polymer Feed, lbs/day

Calculate the polymer fed by the chemical feed pump in pounds of polymer per day.

$$\text{Polymer Feed, lbs/day} = \frac{(\text{Poly Conc, mg}/L)(\text{Vol Pumped, m}L)(60\ \text{min/hr})(24\ \text{hr/day})}{(\text{Time Pumped, min})(1000\ \text{m}L/L)(1000\ \text{mg/gm})(454\ \text{gm/lb})}$$

$$= \frac{(15{,}000\ \text{mg}/L)(800\ \text{m}L)(60\ \text{min/hr})(24\ \text{hr/day})}{(5\ \text{min})(1000\ \text{m}L/L)(1000\ \text{mg/gm})(454\ \text{gm/lb})}$$

$$= 7.6\ \text{lbs polymer/day}$$

EXAMPLE 28

A small chemical feed pump lowered the chemical solution in a three-foot diameter tank one foot and seven inches during an eight-hour period. Estimate the flow delivered by the pump in gallons per minute and gallons per day.

Known

Tank Diameter, ft = 3 ft
Chemical Drop, ft = 1 ft 7 in
Time, hr = 8 hr

Unknown

Flow, GPM
Flow, GPD

1. Convert the tank drop from one foot seven inches to feet.

$$\text{Tank Drop, ft} = 1\ \text{ft} + 7\ \text{inches}$$

$$= 1\ \text{ft} + \frac{7\ \text{in}}{12\ \text{in/ft}}$$

$$= 1\ \text{ft} + 0.58\ \text{ft}$$

$$= 1.58\ \text{ft}$$

2. Determine the gallons of water pumped.

$$\text{Volume Pumped, gal} = (\text{Area, sq ft})(\text{Drop, ft})(7.48\ \text{gal/cu ft})$$

$$= (0.785)(3\ \text{ft})^2(1.58\ \text{ft})(7.48\ \text{gal/cu ft})$$

$$= 83.5\ \text{gal}$$

3. Estimate the flow delivered by the pump in gallons per minute and gallons per day.

$$\text{Flow, GPM} = \frac{\text{Volume Pumped, gal}}{(\text{Time, hr})(60\ \text{min/hr})}$$

$$= \frac{83.5\ \text{gal}}{(8\ \text{hr})(60\ \text{min/hr})}$$

$$= 0.17\ \text{GPM}$$

or

$$\text{Flow, GPD} = \frac{(\text{Volume Pumped, gal})(24\ \text{hr/day})}{\text{Time, hr}}$$

$$= \frac{(83.5\ \text{gal})(24\ \text{hr/day})}{8\ \text{hr}}$$

$$= 250\ \text{GPD}$$

EXAMPLE 29

Determine the settings in percent stroke on a chemical feed pump for various doses of a chemical in milligrams per liter. (The chemical could be chlorine, polymer, potassium permanganate or any other chemical solution fed by a pump.) The pump delivering the water to be treated pumps at a flow rate of 400 GPM. The solution strength of the chemical being pumped is 4.8 percent. The chemical feed pump has a maximum capacity of 92 gallons per day at a setting of 100 percent capacity.

Known		**Unknown**
Pump Flow, GPM	= 400 GPM	Setting, % stroke for various doses in mg/*L*
Solution Strength, %	= 4.8%	
Feed Pump, GPD (100% stroke)	= 92 GPD	

1. Convert the pump flow from gallons per minute to million gallons per day.

$$\text{Pump Flow, MGD} = (\text{Pump Flow, GPM})(60\ \text{min/hr})(24\ \text{hr/day})$$

$$= (400\ \text{gal/min})(60\ \text{min/hr})(24\ \text{hr/day})$$

$$= 576{,}000\ \text{gal/day}$$

$$= 0.576\ \text{MGD}$$

2. Change the chemical solution strength from a percent to pounds of chemical per gallon of solution. A 4.8 percent solution means we have 4.8 pounds of chemical in a solution of water and chemical weighing 100 pounds.

$$\text{Chemical Solution, lbs/gal} = \frac{4.8\ \text{lbs chemical}}{100\ \text{lbs of chemical and water}}$$

$$= \frac{(4.8\ \text{lbs})(8.34\ \text{lbs/gal})}{100\ \text{lbs}}$$

$$= 0.4\ \text{lbs chemical/gallon solution}$$

3. Calculate the chemical feed in pounds per day for a chemical dose of 0.5 milligrams per liter. We are going to assume various chemical doses of 0.5, 1.0, 1.5, 2.0, 2.5 mg/*L* and upward so that if we know the desired chemical dose, we can easily determine the setting (percent stroke) on the chemical feed pump.

$$\text{Chemical Feed, lbs/day} = (\text{Flow, MGD})(\text{Dose, mg}/L)(8.34\ \text{lbs/gal})$$

$$= (0.576\ \text{MGD})(0.5\ \text{mg}/L)(8.34\ \text{lbs/gal})$$

$$= 2.4\ \text{lbs/day}$$

4. Determine the desired flow from the chemical feed pump in gallons per day.

$$\text{Feed Pump, GPD} = \frac{\text{Chemical Feed, lbs/day}}{\text{Chemical Solution, lbs/gal}}$$

$$= \frac{2.4\ \text{lbs/day}}{0.4\ \text{lbs/gal}}$$

$$= 6\ \text{GPD}$$

5. Determine the setting on the chemical feed pump as a percent. In this case we want to know the setting as a percent of the pump stroke.

$$\text{Setting, \%} = \frac{(\text{Desired Feed Pump, GPD})(100\%)}{\text{Maximum Feed Pump, GPD}}$$

$$= \frac{(6\ \text{GPD})(100\%)}{92\ \text{GPD}}$$

$$= 6.5\%$$

6. If we changed the chemical dose in Step 3 from 0.5 mg/*L* to 1.0 mg/*L* and other higher doses and repeated the remainder of the steps, we could calculate the data in Table A.1.

7. Plot the data in Table A.1 (Chemical Dose, mg/*L* vs. Pump Setting, % stroke) to obtain Figure A.3. Only three points were needed since the data plotted a straight line. For any desired chemical dose in milligrams per liter, you can use Figure A.3 to determine the necessary chemical feed pump setting.

TABLE A.1 SETTINGS FOR CHEMICAL FEED PUMP

PUMP FLOW, GPM = 400 GPM

SOLUTION STRENGTH, % = 4.8%

Chemical Dose, mg/*L*	Chemical Feed, lbs/day	Feed Pump, GPD	Pump Setting % stroke
0.5	2.4	6.0	6.5
1.0	4.8	12.0	13.0
1.5	7.2	18.0	19.5
2.0	9.6	24.0	26.1
2.5	12.0	30.0	32.6
3.0	14.4	36.0	39.1
3.5	16.8	42.0	45.6
4.0	19.2	48.0	52.2
4.5	21.6	54.0	58.7
5.0	24.0	60.0	65.2
5.5	26.4	66.0	71.7
6.0	28.8	72.0	78.2
6.5	31.2	78.0	84.8
7.0	33.6	84.0	91.3
7.5	36.0	90.0	97.8

A.139 Blueprint Reading

Example: A set of blueprints for a treatment plant has a scale of 1/4 inch = 1 foot. On the prints, the laboratory dimensions were measured and found to be 6 inches wide and 9 inches long. What is the floor area of the laboratory?

Known		**Unknown**
Scale: 1/4 in	= 1 ft	Area, sq ft
Length	= 9 in	
Width	= 6 in	

$$\text{Area, sq ft} = (\text{Length, ft})\ (\text{Width, ft})$$

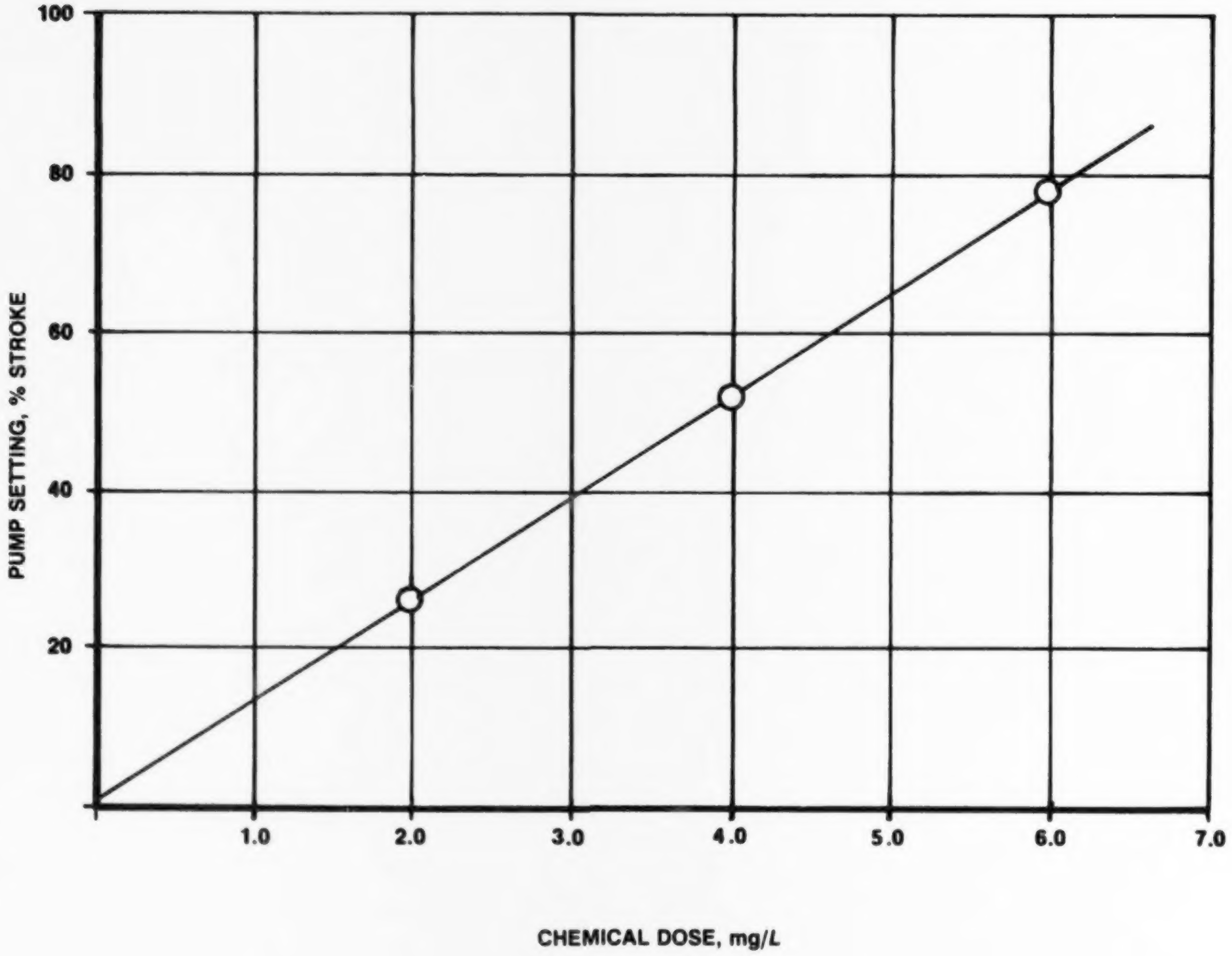


Fig. A.3 Chemical feed pump settings for various chemical doses

Find actual length and width in feet.

$$\frac{1/4\text{ in}}{1\text{ ft}} = \frac{9\text{ in}}{\text{Length, ft}}$$

$$\begin{aligned}\text{Length, ft} &= (9\text{ in})\left[\frac{1\text{ ft}}{1/4\text{ in}}\right]\\ &= (9)(4)\\ &= 36\text{ ft}\end{aligned}$$

$$\frac{1/4\text{ in}}{1\text{ ft}} = \frac{6\text{ in}}{\text{Width, ft}}$$

$$\begin{aligned}\text{Width, ft} &= \frac{(6\text{ in})(1\text{ ft})}{(1/4\text{ in})}\\ &= (6)(4)\\ &= 24\text{ ft}\end{aligned}$$

$$\begin{aligned}\text{Area, sq ft} &= (\text{Length, ft})(\text{Width, ft})\\ &= (36\text{ ft})(24\text{ ft})\\ &= 864\text{ sq ft}\end{aligned}$$

A.14 BASIC CONVERSION FACTORS (METRIC SYSTEM)

LENGTH		
100 cm	= 1 m	100 cm/m
3.281 ft	= 1 m	3.281 ft/m
AREA		
2.4711 ac	= 1 ha*	2.4711 ac/ha
10,000 sq m	= 1 ha	10,000 sq m/ha
VOLUME		
1000 m*L*	= 1 liter	1000 m*L*/*L*
1000 *L*	= 1 cu m	1000 *L*/cu m
3.785 *L*	= 1 gal	3.785 *L*/gal
WEIGHT		
1000 mg	= 1 gm	1000 mg/gm
1000 gm	= 1 kg	1000 gm/kg
DENSITY		
1 kg	= 1 liter	1 kg/*L*
PRESSURE		
10.015 m	= 1 kg/sq cm	10.015 m/kg/sq cm
1 Pascal	= 1 N/sq m	1 Pa/N/sq m
1 psi	= 6895 Pa	1 psi/6895 Pa
FLOW		
3785 cu m/day	= 1 MGD	3785 cu m/day/MGD
3.785 M*L*/day	= 1 MGD	3.785 M*L*/day/MGD

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*hectare

A.15 TYPICAL WASTEWATER TREATMENT PLANT PROBLEMS (METRIC SYSTEM)

A.150 Flows

EXAMPLE 1

Convert a flow of 500 gallons per minute to liters per second and cubic meters per day.

Known	Unknown
Flow, GPM = 500 GPM	1. Flow, liters/sec 2. Flow, cu m/day

1. Convert the flow from 500 GPM to liters per second.

$$\begin{aligned}\text{Flow, liters/sec} &= \frac{(\text{Flow, gal/min})(3.785\text{ liters/gal})}{60\text{ sec/min}}\\ &= \frac{(500\text{ gal/min})(3.785\text{ liters/gal})}{60\text{ sec/min}}\\ &= 31.5\text{ liters/sec}\end{aligned}$$

2. Convert the flow from 500 GPM to cubic meters per day.

$$\begin{aligned}\text{Flow, cu m/day} &= \frac{(\text{Flow, gal/min})(3.785\ L/\text{gal})(60\text{ min/hr})(24\text{ hr/day})}{1000\ L/\text{cu m}}\\ &= \frac{(500\text{ gal/min})(3.785\ L/\text{gal})(60\text{ min/hr})(24\text{ hr/day})}{1000\ L\text{ cu/m}}\\ &= 2725\text{ cu m/day}\end{aligned}$$

A.151 Grit Channels

EXAMPLE 2

Estimate the velocity of wastewater flowing through a grit channel if a stick travels 16 meters in 40 seconds.

Known	Unknown
Distance = 16 m	Velocity, m/sec
Time = 40 sec	

$$\begin{aligned}\text{Velocity, m/sec} &= \frac{\text{Distance Traveled, m}}{\text{Time, sec}}\\ &= \frac{16\text{ m}}{40\text{ sec}}\\ &= 0.4\text{ m/sec}\end{aligned}$$

EXAMPLE 3

A grit channel removed 100 liters of grit during a period when the total flow was 3,000 cubic meters. How many liters of grit are removed per cubic meter?

Known	Unknown
Vol. of Grit = 100 liters	Grit Removed, liters/cu m
Vol. of Flow = 3,000 cu m	

$$\begin{aligned}\text{Grit Removed, } L/\text{cu m} &= \frac{\text{Volume of Grit, liters}}{\text{Volume of Flow, cu m}}\\ &= \frac{100\text{ liters}}{3{,}000\text{ cu m}}\\ &= 0.033\ L/\text{cu m}\end{aligned}$$

A.152 Sedimentation Tanks and Clarifiers

EXAMPLES 4, 5, 6 and 7

A circular secondary clarifier handles a flow of 3,400 cu m/day and a suspended solids of 3600 mg/*L*. The clarifier is 15 meters in diameter and 2.5 meters deep. Find the detention time, surface loading rate, and weir overflow rate.

Known		Unknown
Flow	= 3,400 cu m/day	4. Detention Time, hours
Diameter	= 15 m	5. Surface Loading, cu m/day/sq m
Depth	= 2.5 m	6. Weir Overflow, cu m/day/m
SS	= 3600 mg/L	7. Solids Loading, kg/day/sq m

4. *DETENTION TIME*

$$\text{Detention Time, hrs} = \frac{\text{(Tank Volume, cu m)(24 hr/day)}}{\text{Flow, cu m/day}}$$

$$\text{Tank Volume, cu m} = \text{(Area, sq m)(Depth, m)}$$

$$\begin{aligned}\text{Clarifier Area, sq m} &= 0.785(\text{Diameter, m})^2\\ &= 0.785(15\text{ m})^2\\ &= 176.7\text{ sq m, or}\\ &= 180\text{ sq m}\end{aligned}$$

$$\begin{aligned}\text{Tank Volume, cu m} &= \text{(Area, sq m)(Depth, m)}\\ &= \text{(180 sq m)(2.5 m)}\\ &= 450\text{ cu m}\end{aligned}$$

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{\text{(Tank Volume, cu m)(24 hr/day)}}{\text{Flow, cu m/day}}\\ &= \frac{\text{(450 cu m)(24 hr/day)}}{\text{3,400 cu m/day}}\\ &= \frac{10{,}800}{3{,}400}\\ &= 3.2\text{ hr}\end{aligned}$$

5. *SURFACE LOADING RATE*

$$\begin{aligned}\text{Surface Loading, }\frac{\text{cu m/day}}{\text{sq m}} &= \frac{\text{Flow, cu m/day}}{\text{Area, sq m}}\\ &= \frac{\text{3,400 cu m/day}}{\text{180 sq m}}\\ &= 18.9\text{ cu m/day/sq m}\end{aligned}$$

6. *WEIR OVERFLOW RATE*

$$\text{Weir Overflow, }\frac{\text{cu m/day}}{\text{m}} = \frac{\text{Flow, cu m/day}}{\text{Length of Weir, m}}$$

$$\begin{aligned}\text{Length of Weir, m} &= 3.14(\text{Diameter, m})\\ &= 3.14(15\text{ m})\\ &= 47.1\text{ m}\end{aligned}$$

$$\begin{aligned}\text{Weir Overflow, }\frac{\text{cu m/day}}{\text{m}} &= \frac{\text{Flow, cu m/day}}{\text{Length of Weir, m}}\\ &= \frac{\text{3,400 cu m/day}}{\text{47.1 m}}\\ &= 72\text{ cu m/day/m}\end{aligned}$$

7. *SOLIDS LOADING*

$$\begin{aligned}\text{Solids Applied, kg/day} &= \frac{\text{(Flow, cu m/day)(SS mg/}L\text{)(1000 }L\text{/cu m)}}{\text{(1000 mg/gm)(1000 gm/kg)}}\\ &= \frac{\text{(3400 cu m/day)(3600 mg/}L\text{)(1000 }L\text{/cu m)}}{\text{(1000 mg/gm)(1000 gm/kg)}}\\ &= 12{,}240\text{ kg/day}\end{aligned}$$

$$\begin{aligned}\text{Solids Loading, kg/day/sq m} &= \frac{\text{Solids Applied, kg/day}}{\text{Surface Area, sq m}}\\ &= \frac{\text{12,240 kg/day}}{\text{180 sq m}}\\ &= 68\text{ kg/day/sq m}\end{aligned}$$

A.153 Trickling Filters

EXAMPLES 8 and 9

A flow of 4,300 cubic meters per day is applied to a 15-meter diameter trickling filter which is 1.2 meters deep. The BOD of the wastewater applied to the filter is 120 mg/L. Calculate the hydraulic and organic loadings on the filter.

Known		Unknown
Flow	= 4,300 cu m/day	8. Hydraulic Loading, cu m/day/sq m
Diameter	= 15 m	
Depth	= 1.2 m	9. Organic Loading, kg BOD/day/cu m
BOD	= 120 mg/L	

8. *HYDRAULIC LOADING*

$$\text{Hydraulic Loading, cu m/day/sq m} = \frac{\text{Flow, cu m/day}}{\text{Surface Area, sq m}}$$

$$\begin{aligned}\text{Surface Area, sq m} &= 0.785(\text{Diameter, m})^2\\ &= 0.785(15\text{ m})^2\\ &= 180\text{ sq m}\end{aligned}$$

$$\begin{aligned}\text{Hydraulic Loading, cu m/day/sq m} &= \frac{\text{Flow, cu m/day}}{\text{Surface Area, sq m}}\\ &= \frac{\text{4,300 cu m/day}}{\text{180 sq m}}\\ &= 24\text{ cu m/day/sq m}\end{aligned}$$

9. *ORGANIC LOADING*

$$\text{Organic Loading, }\frac{\text{kg BOD/day}}{\text{cu m}} = \frac{\text{BOD Applied, kg/day}}{\text{Volume of Media, cu m}}$$

$$\text{BOD Applied, kg/day} = \left(\text{BOD, }\frac{\text{mg}}{L}\right)\left(\text{Flow, }\frac{\text{cu m}}{\text{day}}\right)\frac{(1{,}000\ L)}{(1\ \text{cu m})}\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)$$

$$\text{Volume of Media, cu m} = \text{(Surface Area, sq m)(Depth, m)}$$

$$\begin{aligned}\text{BOD Applied, kg/day} &= (\text{BOD, mg/}L)\left(\text{Flow, }\frac{\text{cu m}}{\text{day}}\right)\frac{(1{,}000\ L)}{(1\text{ cu m})}\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)\\ &= (120\text{ mg/}L)\left(4{,}300\ \frac{\text{cu m}}{\text{day}}\right)\frac{(1{,}000\ L)}{(1\text{ cu m})}\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)\\ &= 516\text{ kg BOD/day}\end{aligned}$$

$$\begin{aligned}\text{Volume of Media, cu m} &= \text{(Surface Area, sq m)(Depth, m)}\\ &= \text{(180 sq m)(1.2 m)}\\ &= 216\text{ cu m}\end{aligned}$$

$$\text{Organic Loading, } \frac{\text{kg BOD/day}}{\text{cu m}} = \frac{\text{BOD Applied, kg/day}}{\text{Volume of Media, cu m}}$$

$$= \frac{516 \text{ kg BOD/Day}}{216 \text{ cu m}}$$

$$= 2.4 \text{ kg BOD/day/cu m}$$

EXAMPLE 10

The influent BOD to a trickling filter plant is 200 mg/*L*, and the effluent BOD is 20 mg/*L*. What is the BOD removal efficiency of the plant?

Known

Influent BOD = 200 mg/*L*

Effluent BOD = 20 mg/*L*

Unknown

Plant Efficiency, %

$$\text{Efficiency, \%} = \frac{(\text{In - Out})}{\text{In}} 100\%$$

$$= \frac{(200 \text{ mg/}L - 20 \text{ mg/}L)}{200 \text{ mg/}L} 100\%$$

$$= \frac{180 \text{ mg/}L}{200 \text{ mg/}L} (100\%)$$

$$= 90\%$$

A.154 Rotating Biological Contactors

EXAMPLES 11 and 12

A rotating biological contactor treats a flow of 9.1 MLD (million liters per day or megaliters per day). The surface area of the media is 80,000 square meters. The influent has a total BOD of 220 mg/*L* and suspended solids of 240 mg/*L*. Assume a K value of 0.5 to calculate the soluble BOD. Calculate the hydraulic loading in liters per day per square meter and the organic loading in kilograms of soluble BOD per day per 1000 square meters of media service.

Known

Flow = 9.1 M*L*D

Area = 80,000 sq m

Total BOD = 220 mg/*L*

SS = 240 mg/*L*

K = 0.5

Unknown

11. Hydraulic Loading, *L*/day/sq m
12. Organic Loading, kg BOD/day/1000 sq m

11. *HYDRAULIC LOADING*

$$\text{Hydraulic Loading, } L\text{/day/sq m} = \frac{(\text{Flow, M}L\text{D})(1{,}000{,}000/\text{M})}{\text{Surface Area, sq m}}$$

$$= \frac{(9.1 \text{ M}L\text{D})(1{,}000{,}000/\text{M})}{80{,}000 \text{ sq m}}$$

$$= 114 \ L\text{/day/sq m}$$

12. *ORGANIC LOADING*

$$\text{Soluble BOD, mg/}L = \text{Total BOD, mg/}L - (\text{K})(\text{Suspended Solids, mg/}L)$$

$$= 220 \text{ mg/}L - (0.5)(240 \text{ mg/}L)$$

$$= 100 \text{ mg/}L$$

$$\text{BOD Applied, kg/day} = \frac{(\text{Flow, M}L\text{D})(\text{BOD, mg/}L)(1{,}000{,}000/\text{M})}{(1000 \text{ mg/gm})(1000 \text{ gm/kg})}$$

$$= \frac{(9.1 \text{ M}L\text{D})(100 \text{ mg/}L)(1{,}000{,}000/\text{M})}{(1000 \text{ mg/gm})(1000 \text{ gm/kg})}$$

$$= 910 \text{ kg/day}$$

$$\text{Organic Loading, kg BOD/day/1000 sq m} = \frac{\text{Soluble BOD Applied, kg/day}}{\text{Surface Area of Media, 1000 sq m}}$$

$$= \frac{910 \text{ kg/day}}{80 \cdot 1000 \text{ sq m}}$$

$$= 11.4 \text{ kg BOD/day/1000 sq m}$$

A.155 Activated Sludge

EXAMPLES 13, 14, 15 and 16

Lab results and flow rate for an activated sludge plant are listed below under the known column. Information helpful to the operator in controlling the process is listed in the unknown column. The aerator or aeration tank volume is 2,000 cu m.

Known

Mixed Liquor Suspended Solids (MLSS) = 1,800 mg/*L*

Mixed Liquor Volatile Content = 76%

Thirty-Minute Settleable Solids Test* = 340 m*L*, or 17%

Primary Effluent BOD = 140 mg/*L*

Primary Effluent Suspended Solids = 110 mg/*L*

Flow Rate = 8,000 cu m/day

Unknown

13. Sludge Volume Index, SVI
14. Kilograms of Solids in the Aerator
15. Kilograms of BOD Applied per Day to Aerator
16. Sludge Age, day

13. *SLUDGE VOLUME INDEX*

$$\text{SVI} = \frac{(\text{Settleable Solids, \%})(10{,}000)}{\text{MLSS, mg/}L}$$

$$= \frac{(17)(10{,}000)}{1800}$$

$$= 94$$

14. *KILOGRAMS OF SOLIDS IN AERATOR*

$$\text{Aerator Solids, kg} = (\text{MLSS, mg/}L)(\text{Tank Vol., cu m}) \frac{(1000\ L)}{(1 \text{ cu m})} \left(\frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}}\right)$$

$$= (1800 \text{ mg/}L)\ (2000 \text{ cu m}) \frac{(1000\ L)}{(1 \text{ cu m})} \left(\frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}}\right)$$

$$= 3{,}600 \text{ kg}$$

15. *KILOGRAMS OF BOD APPLIED PER DAY TO AERATOR*

$$\text{Aerator Loading, kg BOD/day} = (\text{P.E. BOD, mg/}L)\left(\text{Flow, } \frac{\text{cu m}}{\text{day}}\right) \frac{(1000\ L)}{(1 \text{ cu m})} \left(\frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}}\right)$$

$$= (140 \text{ mg/}L)\left(8000 \frac{\text{cu m}}{\text{day}}\right) \frac{(1000\ L)}{(1 \text{ cu m})} \left(\frac{1 \text{ kg}}{1{,}000{,}000 \text{ mg}}\right)$$

$$= 1{,}120 \text{ kg BOD/day Applied to Aerator}$$

16. *SLUDGE AGE*

Chapter 11, "Activated Sludge," and Chapter 16, "Laboratory Procedures and Chemistry," discuss the different methods of calculating sludge age and the meaning of the results.

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* Thirty-minute results obtained from 60-minute settleable solids test using 2 liter cylinder.

$$\text{Sludge Age, days} = \frac{(\text{MLSS, mg}/L)(\text{Tank Volume, cu m})\left(\frac{1000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)}{(\text{SS in P.E., mg}/L)\left(\text{Flow, }\frac{\text{cu m}}{\text{day}}\right)\left(\frac{1000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)}$$

$$= \frac{\text{Mixed Liquor Solids, kg}}{\text{Primary Effluent Solids, kg/day}} \quad \text{(or Aerator Solids, kg)}$$

$$= \frac{3600\text{ kg}}{(110\text{ mg}/L)\left(8000\ \frac{\text{cu m}}{\text{day}}\right)\left(\frac{1000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)}$$

$$= \frac{3600\text{ kg}}{880\text{ kg/day}}$$

$$= 4.1\text{ days}$$

A.156 Ponds

EXAMPLES 17, 18, 19 and 20

To calculate the different loadings on a pond, the information listed under known must be available.

Known

Average Depth = 1.2 m
Average Width = 120 m
Average Length = 180 m
Flow = 2,000 cu m/day
BOD = 150 mg/*L*
Population = 5,000 persons

Unknown

Detention time, days
Population Loading, persons/ sq m
Hydraulic Load, cm/day
Organic Load, gm BOD/day/sq m

17. *DETENTION TIME*

$$\text{Detention Time, days} = \frac{\text{Pond Volume, cu m}}{\text{Flow Rate, cu m/day}}$$

$$\text{Pond Area, sq m} = (\text{Average Width, m})(\text{Average Length, m})$$

$$= (120\text{ m})(180\text{ m})$$

$$= 21{,}600\text{ sq m}$$

$$\text{Pond Volume, cu m} = (\text{Area, sq m})(\text{Depth, m})$$

$$= (21{,}600\text{ sq m})(1.2\text{ m})$$

$$= 25{,}920\text{ cu m}$$

$$\text{Flow Rate, cu m/day} = 2000\text{ cu m/day}$$

$$\text{Detention Time, days} = \frac{\text{Pond Volume, cu m}}{\text{Flow Rate, cu m/day}}$$

$$= \frac{25{,}920\text{ cu m}}{2000\text{ cu m/day}}$$

$$= 13.0\text{ days}$$

18. *POPULATION LOADING*

$$\text{Population Loading, persons/sq m} = \frac{\text{Population Served, persons}}{\text{Pond Area, sq m}}$$

$$= \frac{5000\text{ persons}}{21{,}600\text{ sq m}}$$

$$= 0.23\text{ persons/sq m}$$

19. *HYDRAULIC LOADING*

$$\text{Hydraulic Loading, cm/day} = \frac{\text{Depth of Pond, m }(100\text{ cm/m})}{\text{Detention Time, days}}$$

$$= \frac{(1.2\text{ m})(100\text{ cm/m})}{13.0\text{ days}}$$

$$= 9.2\text{ cm/day}$$

20. *ORGANIC LOADING*

$$\text{Organic Loading, gm BOD/day/sq m} = \frac{(\text{BOD, mg}/L)\left(\text{Flow, }\frac{\text{cu m}}{\text{day}}\right)\left(\frac{1000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ gm}}{1000\text{ mg}}\right)}{\text{Area, sq m}}$$

$$= \frac{(150\text{ mg}/L)\left(2{,}000\ \frac{\text{cu m}}{\text{day}}\right)\left(\frac{1000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ gm}}{1000\text{ mg}}\right)}{21{,}600\text{ sq m}}$$

$$= \frac{300{,}000\text{ gm BOD/Day}}{21{,}600\text{ sq m}}$$

$$= 13.9\text{ gm BOD/day/sq m}$$

A.157 Chlorination

EXAMPLE 21

Determine the chlorine demand* of an effluent if the chlorine dose is 10.0 mg/*L* and the chlorine residual is 1.1 mg/*L*.

Known		**Unknown**
Chlorine Dose	= 10.0 mg/*L*	Chlorine Demand, mg/*L*
Chlorine Residual	= 1.1 mg/*L*	

$$\text{Chlorine Demand, mg}/L = \text{Chlor. Dose, mg}/L - \text{Chlor. Residual, mg}/L$$

$$= 10.0\text{ mg}/L - 1.1\text{ mg}/L$$

$$= 8.9\text{ mg}/L$$

EXAMPLE 22

To maintain a satisfactory chlorine residual in a plant effluent, the chlorine dose must be 10 mg/*L* when the flow is 1,400 cu m/day. Determine the chlorinator setting (feed rate) in kilograms per day.

Known		**Unknown**
Dose	= 10 mg/*L*	Chlorinator Setting, kg/day
Flow	= 1,400 cu m/day	

$$\text{Chlorine Feed Rate, kg/day} = (\text{Dose, mg/L})\left(\text{Flow, }\frac{\text{cu m}}{\text{day}}\right)\left(\frac{1{,}000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)$$

$$= (10\text{ mg/L})\left(1400\ \frac{\text{cu m}}{\text{day}}\right)\left(\frac{1{,}000\ L}{1\text{ cu m}}\right)\left(\frac{1\text{ kg}}{1{,}000{,}000\text{ mg}}\right)$$

$$= 14\text{ kg/day}$$

A.158 Chemical Doses

EXAMPLE 23

Determine the chlorinator setting in kilograms per 24 hours if 4000 cubic meters of water per day are to be treated with a desired chlorine dose of 2.5 mg/*L*.

Known		**Unknown**
Flow, cu m/day	= 4000 cu m/day	Chlorinator Setting, kg/24 hours
Chlorine Dose, mg/*L*	= 2.5 mg/*L*	

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* "Standard Methods" uses the term 'chlorine demand' when referring to stabilized water such as a domestic water supply and the term 'chlorination requirement' when referring to wastewater.

Determine the chlorinator setting in kilograms per 24 hours.

$$\text{Chlorinator Setting, kg/day} = \frac{(\text{Flow, cu m/day})(\text{Dose, mg}/L)(1000\ L/\text{cu m})}{(1000\ \text{mg/gm})(1000\ \text{gm/kg})}$$

$$= \frac{(4000\ \text{cu m/day})2.5\ \text{mg}/L)(1000\ L/\text{cu m})}{(1000\ \text{mg/gm})(1000\ \text{gm/kg})}$$

$$= 10\ \text{kg/day}$$

EXAMPLE 24

The optimum liquid polymer dose from the jar tests is 12 mg/*L*. Determine the setting on the liquid polymer chemical feeder in milliliters per minute when the plant flow is 15 megaliters per day (or million liters per day). The liquid polymer delivered to the plant contains 642.3 milligrams of polymer per milliliter of solution.

Known		Unknown
Polymer Dose, mg/*L*	= 12 mg/*L*	Chemical Feeder Setting, m*L*/min
Flow, M*L*/day	= 15 M*L*/day	
Liquid Polymer, mg/m*L*	= 642.3 mg/m*L*	

Calculate the liquid polymer chemical feeder setting in milliliters per minute.

$$\text{Chemical Feeder Setting, m}L\text{/min} = \frac{(\text{Flow, M}L\text{/day})(\text{Polymer Dose, mg}/L)(1{,}000{,}000)}{(\text{Liquid Polymer, mg/m}L)(24\ \text{hr/day})(60\ \text{min/hr})(1\ \text{Million})}$$

$$= \frac{(15\ \text{M}L)(12\ \text{mg}/L)(1{,}000{,}000)}{(642.3\ \text{mg/m}L)(24\ \text{hr/day})(60\ \text{min/hr})(1\ \text{Million})}$$

$$= 195\ \text{m}L\text{/min}$$

EXAMPLE 25

The optimum liquid polymer dose from the jar tests is 8 mg/*L*. Determine the setting on the liquid polymer chemical feeder in milliliters per day when the flow is 12 megaliters per day. The liquid polymer delivered to the plant contains 5.36 pounds of polymer per gallon of liquid solution.

Known		Unknown
Polymer Dose, mg/*L*	= 8 mg/*L*	Chemical Feeder Setting, m*L*/min
Flow, M*L*/day	= 12 M*L*/day	
Liquid Polymer lbs/gal	= 5.36 lbs/gal	

Calculate the liquid polymer chemical feeder setting in milliliters per day.

$$\text{Chemical Feeder Setting, m}L\text{/min} = \frac{(\text{Flow, M}L\text{/day})(\text{Polymer Dose, mg}/L)(3.785\ L\text{/gal})(1000\ \text{m}L/L)(1{,}000{,}000)}{(\text{Liquid Polymer, lbs/gal})(454\ \text{gm/lb})(1000\ \text{mg/gm})(24\ \text{hr/day})(60\ \text{min/hr})(1\ \text{Million})}$$

$$= \frac{(12\ \text{M}L\text{/day})(8\ \text{mg}/L)(3.785\ L\text{/gal})(1000\ \text{m}L/L)(1{,}000{,}000)}{(5.36\ \text{lbs/gal})(454\ \text{gm/lb})(1000\ \text{mg/gm})(24\ \text{hr/day})(60\ \text{min/hr})(1\ \text{Million})}$$

$$= 104\ \text{m}L\text{/min}$$

EXAMPLE 26

Determine the actual chemical dose or chemical feed in kilograms per day from a dry chemical feeder. A bucket placed under the chemical feeder weighed 150 grams empty and 1800 grams after 12 minutes.

Known		Unknown
Empty Bucket, gm	= 150 gm	Chemical Feed, kg/day
Full Bucket, gm	= 1800 gm	
Time to fill, min	= 12 min	

$$\text{Chemical Feed, kg/day} = \frac{\text{Chemical Applied, kg}}{\text{Length of Application, days}}$$

$$= \frac{(1800\ \text{gm} - 150\ \text{gm})(60\ \text{min/hr})(24\ \text{hr/day})}{(1000\ \text{gm/kg})(12\ \text{min})}$$

$$= 198\ \text{kg/day}$$

EXAMPLE 27

Determine the chemical feed in kilograms of polymer per day from a chemical feed pump. The polymer solution is 1.5 percent or 15,000 mg polymer per liter. Assume a specific gravity of the polymer solution of 1.0. During a test run the chemical feed pump delivered 800 m*L* of polymer solution during five minutes.

Known		Unknown
Polymer Solution, %	= 1.5%	Polymer Feed, kg/day
Polymer Conc, mg/*L*	= 15,000 mg/*L*	
Polymer Sp Gr	= 1.0	
Vol Pumped, m*L*	= 800 m*L*	
Time Pumped, min	= 5 min	

Calculate the polymer fed by the chemical feed pump in kilograms of polymer per day.

$$\text{Polymer Feed, kg/day} = \frac{(\text{Poly Conc, mg}/L)(\text{Vol Pumped, m}L)(60\ \text{min/hr})(24\ \text{hr/day})}{(\text{Time Pumped, min})(1000\ \text{m}L/L)(1000\ \text{mg/gm})(1000\ \text{gm/kg})}$$

$$= \frac{(15{,}000\ \text{mg}/L)(800\ \text{m}L)(60\ \text{min/hr})(24\ \text{hr/day})}{(5\ \text{min})(1000\ \text{m}L/L)(1000\ \text{mg/gm})(1000\ \text{gm/kg})}$$

$$= 3.5\ \text{kg/day}$$

EXAMPLE 28

A small chemical feed pump lowered the chemical solution in an 80-centimeter diameter tank 35 centimeters during an eight-hour period. Estimate the flow delivered by the pump in liters per minute.

Known		Unknown
Tank Diameter, cm	= 80 cm	Flow, liters/min
Chemical Drop, cm	= 35 cm	
Time, hr	= 8 hr	

Calculate the flow in liters per minute.

$$\text{Flow, liters/min} = \frac{(\text{Area, sq m})(\text{Drop, m})(1000\ \text{liters/cu m})}{(\text{Time, hr})(60\ \text{min/hr})}$$

$$= \frac{(0.785)(0.8\ \text{m})^2(0.35\ \text{m})(1000\ \text{liters/cu m})}{(8\ \text{hr})(60\ \text{min/hr})}$$

$$= 0.37\ \text{liters/min}$$

EXAMPLE 29

Determine the settings in percent stroke on a chemical feed pump for various doses of a chemical in milligrams per liter. (The chemical could be chlorine, polymer, potassium permanganate or any other chemical solution fed by a pump.) The pump delivering water to be treated pumps at a flow rate of 25 liters per second. The solution strength of the chemical being pumped is five percent. The chemical feed pump has a maximum capacity of 250 milliliters per minute at a setting of 100 percent capacity.

Known		Unknown
Pump Flow, *L*/sec	= 25 *L*/sec	Settings, % stroke for various doses in mg/*L*
Solution Strength, %	= 5%	
Feed Pump, m*L*/min (100% stroke)	= 250 m*L*/min	

1. Change the chemical solution strength from a percent to milligrams of chemical per liter of solution. A 5 percent solution means we have 5 milligrams of chemical in a solution of water and chemical weighing 100 milligrams.

$$\text{Chemical Solution, mg}/L = \frac{5 \text{ mg chemical}}{100 \text{ mg of chemical and water}}$$

$$= \frac{(5 \text{ mg})(1{,}000{,}000 \text{ mg}/L)}{100 \text{ mg}}$$

$$= 50{,}000 \text{ mg}/L$$

2. Calculate the chemical feed in kilograms per day for a chemical dose of 0.5 milligrams per liter. We are going to assume various chemical doses of 0.5, 1.0, 1.5, 2.0, 2.5 mg/*L* and upward so that if we know the desired chemical dose, we can easily determine the setting (percent stroke) on the chemical feed pump.

$$\text{Chemical Feed, kg/day} = \frac{(\text{Flow, } L/\text{sec})(\text{Dose, mg}/L)(60 \text{ sec/min})(60 \text{ min/hr})(24 \text{ hr/day})}{1{,}000{,}000 \text{ mg/kg}}$$

$$= \frac{(25\ L/\text{sec})(0.5 \text{ mg}/L)(60 \text{ sec/min})(60 \text{ min/hr})(24 \text{ hr/day})}{1{,}000{,}000 \text{ mg/kg}}$$

$$= 1.1 \text{ kg/day}$$

3. Determine the desired flow from the chemical feed pump in milliliters per minute.

$$\text{Feed Pump, m}L/\text{min} = \frac{\text{Chemical Feed, kg/day}}{\text{Chemical Solution, mg}/L}$$

$$= \frac{(1.1 \text{ kg/day})(1000 \text{ m}L/L)(1{,}000{,}000 \text{ mg/kg})}{(50{,}000 \text{ mg}/L)(24 \text{ hr/day})(60 \text{ min/hr})}$$

$$= 15.3 \text{ m}L/\text{min}$$

4. Determine the setting in the chemical feed pump as a percent. In this case we want to know the setting as a percent of the pump stroke.

$$\text{Setting, \%} = \frac{(\text{Desired Feed Pump, m}L/\text{min})(100\%)}{\text{Maximum Feed Pump, m}L/\text{min}}$$

$$= \frac{(15.3 \text{ m}L/\text{min})(100\%)}{250 \text{ m}L/\text{min}}$$

$$= 6.1\%$$

5. If we changed the chemical dose in Step 2 from 0.5 mg/*L* to 1.0 mg/*L* and other higher doses and repeated the remainder of the steps, we could calculate the data in Table A.2.

TABLE A.2 SETTINGS FOR CHEMICAL FEED PUMP

PUMP FLOW, *L*/sec = 25 *L*/sec

SOLUTION STRENGTH, % = 5.0%

Chemical Dose, mg/*L*	Chemical Feed, kg/day	Feed Pump, m*L*/min	Pump Setting, % stroke
0.5	1.1	15.3	6.1
1.0	2.2	30.6	12.2
2.0	4.3	59.7	23.9
4.0	8.6	119.4	47.8
6.0	13.0	180.6	72.2
8.0	17.3	240.3	96.0

6. The data in Table A.2 could be plotted to produce a chart similar to Figure A.3 (page 438). For any desired chemical dose in milligrams per liter, the chart could be used to determine the necessary chemical feed pump setting.

A.159 Blueprint Reading

Example: A set of blueprints for a treatment plant has a scale of 1:100. On the prints, the laboratory dimensions were measured and found to be 70 mm wide and 100 mm long. What is the floor area of the laboratory?

Known		Unknown
Scale	= 1:100	Area, sq m
Length	= 100 mm	
Width	= 70 mm	

Area, sq m = (Length, m)(Width, m)

Find actual length and width in meters.

$$\frac{1}{100} = \frac{100 \text{ mm}}{\text{Length, m}}$$

$$\text{Length, m} = 100 \text{ mm} \frac{(100)}{(1)} \frac{(1 \text{ m})}{(1{,}000 \text{ mm})}$$

$$= 10 \text{ m}$$

$$\frac{1}{100} = \frac{70 \text{ mm}}{\text{Width, m}}$$

$$\text{Width, m} = (70 \text{ mm}) \frac{(100)}{(1)} \frac{(1 \text{ m})}{(1{,}000 \text{ mm})}$$

$$= 7 \text{ m}$$

$$\text{Area, sq ft} = (\text{Length, m})(\text{Width, m})$$

$$= (10 \text{ m})(7 \text{ m})$$

$$= 70 \text{ sq m}$$

GLOSSARY

A Summary of the Words Defined

in

OPERATION OF WASTEWATER TREATMENT PLANTS

Project Pronunciation Key

by Warren L. Prentice

The Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This key is designed solely to aid operators in this program.

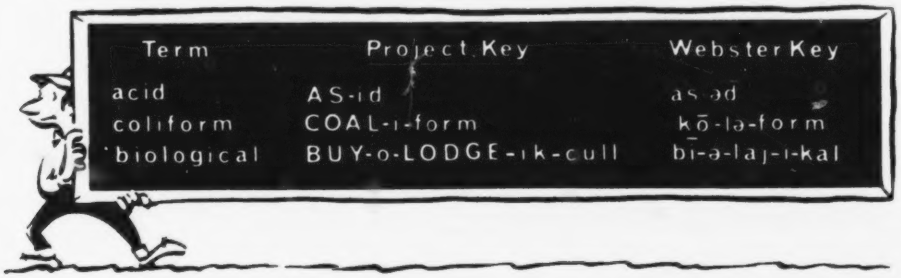
You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation key. Each key will be different from each other and from this key. Examples of the difference between the key used in this program and the Webster's *NEW WORLD DICTIONARY* "Key"[1] are shown below:

In using this key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Project Key.

	SYLLABLE				
WORD	1st	2nd	3rd	4th	5th
acid	AS	id			
coagulant	co	AGG	you	lent	
biological	BUY	o	LODGE	ik	cull

The first word, *ACID*, has its first syllable accented. The second word, *COAGULANT*, has its second syllable accented. The third word, *BIOLOGICAL*, has its first and third syllables accented.

We hope you will find the key useful in unlocking the pronunciation of any new word.



Term	Project Key	Webster Key
acid	AS-id	as-əd
coliform	COAL-i-form	kō-lə-form
biological	BUY-o-LODGE-ik-cull	bī-ə-laj-i-kal

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[1] *The Webster's* NEW WORLD DICTIONARY, *College Edition, 1968, was chosen rather than an unabridged dictionary because of its availability to the operator.*

GLOSSARY

ABS ABS

Alkyl **B**enzene **S**ulfonate. A type of surfactant, or surface active agent, present in synthetic detergents in the United States before 1965. ABS was especially troublesome because it caused foaming and resisted breakdown by biological treatment processes. ABS has been replaced in detergents by **l**inear **a**lkyl **s**ulfonate (LAS) which is biodegradable.

ABSORPTION (ab-SORP-shun) ABSORPTION

Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACID ACID

(1) A substance that tends to lose a proton. (2) A substance that dissolves in water with the formation of hydrogen ions. (3) A substance containing hydrogen which may be replaced by metals to form salts.

ACIDITY ACIDITY

The capacity of water or wastewater to neutralize bases. Acidity is expressed in milligrams per liter of equivalent calcium carbonate. Acidity is not the same as pH because water does not have to be strongly acidic (low pH) to have a high acidity. Acidity is a measure of how much base can be added to a liquid without causing a great change in pH.

ACTIVATED SLUDGE (ACK-ta-VATE-ed slug) ACTIVATED SLUDGE

Sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, fungi, and protozoa. Activated sludge is different from primary sludge in that the sludge particles contain many living organisms which can feed on the incoming wastewater.

ACTIVATED SLUDGE PROCESS (ACK-ta-VATE-ed sluj) ACTIVATED SLUDGE PROCESS

A biological wastewater treatment process which speeds up the decomposition of wastes in the wastewater being treated. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.

ADSORPTION (add-SORP-shun) ADSORPTION

The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another substance.

ADVANCED WASTE TREATMENT ADVANCED WASTE TREATMENT

Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration. Also called TERTIARY TREATMENT.

AERATION (air-A-shun) AERATION

The process of adding air. In wastewater treatment, air is added to freshen wastewater and to keep solids in suspension. With mixtures of wastewater and activated sludge, adding air provides mixing and oxygen for the microorganisms treating the wastewater.

AERATION LIQUOR (air-A-shun) AERATION LIQUOR

Mixed liquor. The contents of the aeration tank including living organisms and material carried into the tank by either untreated wastewater or primary effluent.

AERATION TANK (air-A-shun) AERATION TANK

The tank where raw or settled wastewater is mixed with return sludge and aerated. The same as aeration bay, aerator, or reactor.

AEROBES AEROBES

Bacteria that must have molecular (dissolved) oxygen (DO) to survive. Aerobes are aerobic bacteria.

AEROBIC (AIR-O-bick) AEROBIC

A condition in which "free" or dissolved oxygen is present in the aquatic environment.

AEROBIC BACTERIA (AIR-O-bick back-TEAR-e-ah) AEROBIC BACTERIA

Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobic bacteria.

AEROBIC DECOMPOSITION (AIR-O-bick) AEROBIC DECOMPOSITION

The decay or breaking down of organic material in the presence of "free" or dissolved oxygen.

AEROBIC DIGESTION (AIR-O-bick) AEROBIC DIGESTION

The breakdown of wastes by microorganisms in the presence of dissolved oxygen. Waste sludge is placed in a large aerated tank where aerobic microorganisms decompose the organic matter in the sludge. This is an extension of the activated sludge process.

AEROBIC PROCESS (AIR-O-bick) AEROBIC PROCESS

A waste treatment process conducted under aerobic (in the presence of "free" or dissolved oxygen) conditions.

AGGLOMERATION (a-GLOM-er-A-shun) AGGLOMERATION

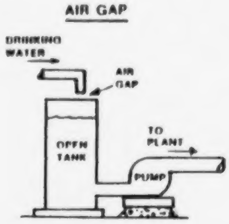
The growing or coming together of small scattered particles into larger flocs or particles which settle rapidly. Also see FLOC.

AIR BINDING AIR BINDING

The clogging of a filter, pipe or pump due to the presence of air released from water.

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use in a wastewater treatment plant. This gap prevents back siphonage because there is no way wastewater can reach the drinking water.



AIR LIFT AIR LIFT

A special type of pump. This device consists of a vertical riser pipe submerged in the wastewater or sludge to be pumped. Compressed air is injected into a tail piece at the bottom of the pipe. Fine air bubbles mix with the wastewater or sludge to form a mixture lighter than the surrounding water which causes the mixture to rise in the discharge pipe to the outlet. An airlift pump works similar to the center stand in a percolator coffee pot.

AIR PADDING AIR PADDING

Pumping dry air into a container to assist with the withdrawal of a liquid or to force a liquid gas such as chlorine or sulfur dioxide out of a container.

ALGAE (AL-gee) ALGAE

Microscopic plants which contain chlorophyll and float or are suspended and live in water. They also may be attached to structures, rocks, or other similar substances.

ALIQUOT (AL-li-kwot) ALIQUOT

Portion of a sample.

ALKALI ALKALI

Any of certain soluble salts, principally of sodium, potassium, magnesium, and calcium, that have the property of combining with acids to form neutral salts and may be used in chemical processes such as water or wastewater treatment.

ALKALINITY (AL-ka-LIN-ity) ALKALINITY

The capacity of water or wastewater to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.

AMBIENT TEMPERATURE (AM-bee-ent) AMBIENT TEMPERATURE

Temperature of the surroundings.

AMPEROMETRIC (am-PURR-o-MET-rick) AMPEROMETRIC

A method of measurement that records electric current flowing or generated, rather than recording voltage. Amperometric titration is a means of measuring concentrations of certain substances in water.

ANAEROBES ANAEROBES

Bacteria that do not need molecular (dissolved) oxygen (DO) to survive.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" or dissolved oxygen is *NOT* present in the aquatic environment.

ANAEROBIC BACTERIA (AN-air-O-bick back-TEAR-e-ah) ANAEROBIC BACTERIA

Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4).

ANAEROBIC DECOMPOSITION (AN-air-O-bick) ANAEROBIC DECOMPOSITION

The decay or breaking down of organic material in an environment containing no "free" or dissolved oxygen.

ANAEROBIC DIGESTION (AN-air-O-bick) ANAEROBIC DIGESTION

Wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen. At least two general groups of bacteria act in balance: (1) *SAPROPHYTIC* bacteria break down complex solids to volatile acids, and (2) *METHANE FERMENTERS* break down the acids to methane, carbon dioxide, and water.

ANHYDROUS (an-HI-drous) ANHYDROUS

Very dry. No water or dampness is present.

ANION ANION

A negatively charged ion in an electrolyte solution, attracted to the anode under the influence of electric potential.

ASEPTIC (a-SEP-tick) ASEPTIC

Free from the living germs of disease, fermentation or putrefaction. Sterile.

ASPIRATE (ASS-per-RATE) ASPIRATE

Use of a hydraulic device (aspirator or eductor) to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump; sometimes used instead of a sump pump.

BOD (BEE-OH-DEE) BOD

Biochemical Oxygen Demand. The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BTU (BEE-TEA-YOU) BTU

British Thermal Unit. The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

BACTERIA (back-TEAR-e-ah) BACTERIA

Bacteria are living organisms, microscopic in size, which consist of a single cell. Most bacteria utilize organic matter for their food and produce waste products as the result of their life processes.

BACTERIAL CULTURE (back-TEAR-e-al) BACTERIAL CULTURE

In the case of activated sludge, the bacterial culture refers to the group of bacteria classed as *AEROBES*, and facultative organisms, which covers a wide range of organisms. Most treatment processes in the United States grow facultative organisms which utilize the carbonaceous (carbon compounds) BOD. Facultative organisms can live when oxygen resources are low. When "nitrification" is required, the nitrifying organisms are *OBLIGATE AEROBES* (require oxygen) and must have at least 0.5 mg/*L* of dissolved oxygen throughout the whole system to function properly.

BAFFLE BAFFLE

A flat board or plate, deflector, guide or similar device constructed or placed in flowing water, wastewater, or slurry systems to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate liquids.

BASE BASE

A compound which dissociates in aqueous solution to yield hydroxyl ions.

BATCH PROCESS BATCH PROCESS

A treatment process in which a tank or reactor is filled, the water is treated, and the tank is emptied. The tank may then be filled and the process repeated.

BIOASSAY (BUY-o-ass-SAY) BIOASSAY

(1) A way of showing or measuring the effect of biological treatment on a particular substance or waste, or (2) a method of determining toxic effects of industrial wastes or other wastes by using live organisms such as fish for test organisms.

BIOCHEMICAL OXYGEN DEMAND (BOD) BIOCHEMICAL OXYGEN DEMAND (BOD)

The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BIOCHEMICAL OXYGEN DEMAND (BOD) TEST BIOCHEMICAL OXYGEN DEMAND (BOD) TEST

A procedure that measures the rate of oxygen use under controlled conditions of time and temperature. Standard test conditions include dark incubation at 20°C for a specified time (usually five days).

BIODEGRADABLE (BUY-o-dee-GRADE-able) BIODEGRADABLE

Organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odors.

BIODEGRADATION (BUY-o-de-grah-DAY-shun) BIODEGRADATION

The breakdown of organic matter by bacteria to more stable forms which will not create a nuisance or give off foul odors.

BIOFLOCCULATION (BUY-o-flock-u-LAY-shun) BIOFLOCCULATION

The clumping together of fine, dispersed organic particles by the action of certain bacteria and algae. This results in faster and more complete settling of the organic solids in wastewater.

BIOMASS (BUY-o-MASS) BIOMASS

A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris. This mass may be formed for, or function as, the protection against predators and storage of food supplies. Also see ZOOGLEAL MASS.

BLANK BLANK

A bottle containing only dilution water or distilled water, but the sample being tested is not added. Tests are frequently run on a *SAMPLE* and a *BLANK* and the differences compared.

BLINDING BLINDING

The clogging of the filtering medium of a microscreen or a vacuum filter when the holes or spaces in the media become sealed off due to grease or the material being filtered.

BOUND WATER BOUND WATER

Water contained within the cell mass of sludges or strongly held on the surface of colloidal particles.

BREAKOUT OF CHLORINE BREAKOUT OF CHLORINE

A point at which chlorine leaves solution as a gas because the chlorine feed rate is too high. The solution is saturated and cannot dissolve any more chlorine.

BREAKPOINT CHLORINATION BREAKPOINT CHLORINATION

Addition of chlorine to water or wastewater until the chlorine demand has been satisfied and further additions of chlorine result in a residual that is directly proportional to the amount added beyond the breakpoint.

BUFFER BUFFER

A solution or liquid whose chemical makeup neutralizes acids or bases without a great change in pH.

BUFFER ACTION BUFFER ACTION

The action of certain ions in solution in opposing a change in hydrogen-ion concentration.

BUFFER CAPACITY BUFFER CAPACITY

A measure of the capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water or wastewater for offering a resistance to changes in pH.

BUFFER SOLUTION BUFFER SOLUTION

A solution containing two or more substances which, in combination, resist any marked change in pH following addition of moderate amounts of either strong acid or base.

BULKING (BULK-ing) BULKING

Clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge becomes too light and will not settle properly.

CALORIE (KAL-o-ree) CALORIE

The amount of heat required to raise the temperature of one gram of water one degree Celsius.

CARBONACEOUS STAGE (car-bun-NAY-shus) CARBONACEOUS

A stage of decomposition that occurs in biological treatment processes when aerobic bacteria, using dissolved oxygen, change carbon compounds to carbon dioxide. Sometimes referred to as "first-stage BOD" because the microorganisms attack organic or carbon compounds first and nitrogen compounds later. Also see NITRIFICATION STAGE.

CATHODIC PROTECTION (ca-THOD-ick) CATHODIC PROTECTION

An electrical system for prevention of rust, corrosion, and pitting of steel and iron surfaces in contact with water, wastewater or soil.

CATION EXCHANGE CAPACITY CATION EXCHANGE CAPACITY

The ability of a soil or other solid to exchange cations (positive ions such as calcium, Ca^{+2}) with a liquid.

CAVITATION (CAV-i-TAY-shun) CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.

CENTRATE CENTRATE

The water leaving a centrifuge after most of the solids have been removed.

CENTRIFUGE CENTRIFUGE

A mechanical device that uses centrifugal or rotational forces to separate solids from liquids.

CHEMICAL EQUIVALENT CHEMICAL EQUIVALENT

The weight in grams of a substance that combines with or displaces one gram of hydrogen. Chemical equivalents usually are found by dividing the formula weight by its valence.

CHEMICAL OXYGEN DEMAND or COD CHEMICAL OXYGEN DEMAND or COD

A measure of the oxygen-consuming capacity of inorganic and organic matter present in wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in mg/*L* during a specific test. Results are not necessarily related to the biochemical oxygen demand because the chemical oxidant may react with substances that bacteria do not stabilize.

CHEMICAL PRECIPITATION CHEMICAL PRECIPITATION

(1) Precipitation induced by addition of chemicals. (2) The process of softening water by the addition of lime or lime and soda ash as the precipitants.

CHLORAMINES (KLOR-a-means) CHLORAMINES

Chloramines are compounds formed by the reaction of chlorine with ammonia.

CHLORINATION (KLOR-i-NAY-shun) CHLORINATION

The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

CHLORINE DEMAND CHLORINE DEMAND

Chlorine demand is the difference between the amount of chlorine added to wastewater and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of the impurities in the water.

$$\text{Chlorine Demand, mg}/L = \text{Chlorine Applied, mg}/L - \text{Chlorine Residual, mg}/L$$

CHLORINE REQUIREMENT CHLORINE REQUIREMENT

The amount of chlorine which is needed for a particular purpose. Some reasons for adding chlorine are reducing the number of coliform bacteria (Most Probable Number), obtaining a particular chlorine residual, or destroying some chemical in the water. In each case a definite dosage of chlorine will be necessary. This dosage is the chlorine requirement.

CHLORORGANIC (chloro-or-GAN-nick) CHLORORGANIC

Chlororganic compounds are organic compounds combined with chlorine. These compounds generally originate from, or are associated with, living or dead organic materials.

CILIATES (SILLY-ates) CILIATES

A class of protozoans distinguished by short hairs on all or part of their bodies.

CLARIFICATION (KLAIR-i-fi-KAY-shun) CLARIFICATION

Any process or combination of processes the main purpose of which is to reduce the concentration of suspended matter in a liquid.

CLARIFIER (KLAIR-i-fire) CLARIFIER

Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time, during which the heavier solids settle to the bottom and the lighter material will float to the water surface.

COAGULANT AID COAGULANT AID

Any chemical or substance used to assist or modify coagulation.

COAGULANTS (co-AGG-you-lents) COAGULANTS

Chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COAGULATION (co-AGG-you-LAY-shun) COAGULATION

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COLIFORM (COAL-i-form) COLIFORM

One type of bacteria. The presence of coliform-group bacteria is an indication of possible pathogenic bacterial contamination. The human intestinal tract is one of the main habitats of coliform bacteria. They may also be found in the intestinal tracts of warm-blooded animals, and in plants, soil, air, and the aquatic environment. Fecal coliforms are those coliforms found in the feces of various warm-blooded animals; whereas the term "coliform" also includes other environmental sources.

COLLOIDS (KOL-loids) COLLOIDS

Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

COLORIMETRIC MEASUREMENT COLORIMETRIC MEASUREMENT

A means of measuring unknown concentrations of water quality indicators in a sample by measuring the sample's color intensity. The color of the sample after the addition of specific chemicals (reagents) is compared with colors of known concentrations.

COMBINED AVAILABLE CHLORINE COMBINED AVAILABLE CHLORINE

The concentration of chlorine which is combined with ammonia (NH_3) as chloramine or as other chloro derivatives, yet is still available to oxidize organic matter.

COMBINED AVAILABLE RESIDUAL CHLORINE COMBINED AVAILABLE RESIDUAL CHLORINE

That portion of the total residual chlorine which remains in water or wastewater at the end of a specified contact period and reacts chemically and biologically as chloramines or organic chloramines.

COMBINED RESIDUAL CHLORINATION COMBINED RESIDUAL CHLORINATION

The application of chlorine to water or wastewater to produce a combined chlorine residual. The residual may consist of chlorine compounds formed by the reaction of chlorine with natural or added ammonia (NH_3) or with certain organic nitrogen compounds.

COMBINED SEWER COMBINED SEWER

A sewer designed to carry both sanitary wastewaters and storm- or surface-water runoff.

COMMINUTION (com-mi-NEW-shun) COMMINUTION

Shredding. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment. *COMMINUTION* and *SHREDDING* usually mean the same thing.

COMMINUTOR (com-mi-NEW-ter) COMMINUTOR

A device used to reduce the size of the solid chunks in wastewater by shredding (comminuting). The shredding action is like many scissors cutting or chopping to shreds all the large influent solids material.

5.0

COMPOSITE (PROPORTIONAL) SAMPLE (com-POZ-it) COMPOSITE (PROPORTIONAL) SAMPLE

A composite sample is a collection of individual samples obtained at regular intervals, usually every one or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture (composite sample) forms a representative sample and is analyzed to determine the average conditions during the sampling period.

COMPOUND COMPOUND

A pure substance composed of two or more elements whose composition is constant. For example, table salt (sodium chloride - Na Cl) is a compound.

CONING (CONE-ing) CONING

Development of a cone-shaped flow of liquid, like a whirlpool, through sludge. This can occur in a sludge hopper during sludge withdrawal when the sludge becomes too thick. Part of the sludge remains in place while liquid rather than sludge flows out of the hopper. Also called "coring."

CONTACT STABILIZATION CONTACT STABILIZATION

Contact stabilization is a modification of the conventional activated sludge process. In contact stabilization, two aeration tanks are used. One tank is for separate re-aeration of the return sludge for at least four hours before it is permitted to flow into the other aeration tank to be mixed with the primary effluent requiring treatment.

CONTINUOUS PROCESS CONTINUOUS PROCESS

A treatment process in which water is treated continuously in a tank or reactor. The water being treated continuously flows into the tank at one end, is treated as it flows through the tank, and flows out the opposite end as treated water.

CONVENTIONAL TREATMENT CONVENTIONAL TREATMENT

The pretreatment, sedimentation, flotation, trickling filter, activated sludge and chlorination wastewater treatment processes.

CROSS CONNECTION CROSS CONNECTION

A connection between drinking (potable) water and an unsafe water supply. For example, if you have a pump moving nonpotable water and hook into the drinking water system to supply water for the pump seal, a cross connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

CRYOGENIC (cry-o-JEN-nick) CRYOGENIC

Low temperature.

DO (DEE-OH) DO

Abbreviation of Dissolved Oxygen. DO is the atmospheric oxygen dissolved in water or wastewater.

DATEOMETER (day-TOM-uh-ter) DATEOMETER

A small calendar disc attached to motors and equipment to indicate the year in which the last maintenance service was performed.

DECHLORINATION (dee-KLOR-i-NAY-shun) DECHLORINATION

The removal of chlorine from the effluent of a treatment plant.

DECIBEL DECIBEL

A unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average pain level.

DECOMPOSITION, DECAY DECOMPOSITION, DECAY

Processes that convert unstable materials into more stable forms by chemical or biological action. Waste treatment encourages decay in a controlled situation so that material may be disposed of in a stable form. When organic matter decays under anaerobic conditions (putrefaction), undesirable odors are produced. The aerobic processes in common use for wastewater treatment produce much less objectional odors.

DEGRADATION (de-grah-DAY-shun) DEGRADATION

The conversion of a substance to simpler compounds. For example, the degradation of organic matter to carbon dioxide and water.

DENITRIFICATION DENITRIFICATION

A condition that occurs when nitrite or nitrate ions are reduced to nitrogen gas and bubbles are formed as a result of this process. The bubbles attach to the biological flocs and float the flocs to the surface of the secondary clarifiers. This condition is often the cause of rising sludge observed in secondary clarifiers.

DENSITY (DEN-sit-tee) **DENSITY**

A measure of how heavy a substance (solid, liquid or gas) is for its size. Density is expressed in terms of weight per unit volume, that is, grams per cubic centimeter or pounds per cubic foot. The density of water (at 4°C or 39°F) is 1.0 gram per cubic centimeter or about 62.4 pounds per cubic foot.

DESICCATOR (DESS-i-KAY-tor) **DESICCATOR**

A closed container into which heated weighing or drying dishes are placed to cool in a dry environment. The dishes may be empty or they may contain a sample. Desiccators contain a substance, such as anhydrous calcium chloride, which absorbs moisture and keeps the relative humidity near zero so that the dish or sample will not gain weight from absorbed moisture.

DETENTION TIME **DETENTION TIME**

The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DETRITUS (dee-TRI-tus) **DETRITUS**

The heavy, coarse mixture of grit and organic material carried by wastewater.

DEW POINT **DEW POINT**

The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air.

DEWATER **DEWATER**

To remove or separate a portion of the water present in a sludge or slurry.

DEWATERABLE **DEWATERABLE**

This is a property of a sludge related to the ability to separate the liquid portion from the solid, with or without chemical conditioning. A material is considered dewaterable if water will readily drain from it.

DIAPHRAGM PUMP **DIAPHRAGM PUMP**

The pump in which a flexible diaphragm, generally of rubber or equally flexible material, is the operating part. It is fastened at the edges in a vertical cylinder. When the diaphragm is raised suction is exerted, and when it is depressed, the liquid is forced through a discharge valve.

DIFFUSED-AIR AERATION **DIFFUSED-AIR AERATION**

A diffused air activated sludge plant takes air, compresses it, and then discharges the air below the water surface of the aerator through some type of air diffusion device.

DIFFUSER **DIFFUSER**

A device (porous plate, tube, bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

DIGESTER (die-JEST-er) **DIGESTER**

A tank in which sludge is placed to allow decomposition by microorganisms. Digestion may occur under anaerobic (more common) or aerobic conditions.

DISCHARGE HEAD **DISCHARGE HEAD**

The pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the discharge side of a pump. The pressure can be measured from the center line of the pump to the hydraulic grade line of the water in the discharge pipe.

DISINFECTION (dis-in-FECT-shun) **DISINFECTION**

The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being most frequently used in water and wastewater treatment plants. Compare with STERILIZATION.

DISSOLVED OXYGEN **DISSOLVED OXYGEN**

Molecular oxygen dissolved in water or wastewater, usually abbreviated DO.

DISTILLATE (DIS-tuh-late) **DISTILLATE**

In the distillation of a sample, a portion is evaporated; the part that is condensed afterwards is the distillate.

DISTRIBUTOR **DISTRIBUTOR**

The rotating mechanism that distributes the wastewater evenly over the surface of a trickling filter or other process unit. Also see FIXED SPRAY NOZZLE.

DOCTOR BLADE
DOCTOR BLADE

A blade used to remove any excess solids that may cling to the outside of a rotating screen.

DROOP
DROOP

The difference between the actual value and the desired value (or set point) characteristics of proportional controllers that do not incorporate reset action. Also called OFFSET.

DYNAMIC HEAD
DYNAMIC HEAD

When a pump is operating, the vertical distance (in feet or meters) from a point to the energy grade lines. Also see TOTAL DYNAMIC HEAD and STATIC HEAD.

EDUCTOR (e-DUCK-tor)
EDUCTOR

A hydraulic device used to create a negative pressure (suction) by forcing a liquid through a restriction, such as a Venturi. An eductor or aspirator (the hydraulic device) may be used in the laboratory in place of a vacuum pump; sometimes used instead of a suction pump.

EFFLORESCENCE (EF-low-RESS-ense)
EFFLORESCENCE

The powder or crust formed on a substance when moisture is given off upon exposure to the atmosphere.

EFFLUENT (EF-lu-ent)
EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

ELECTRO-CHEMICAL PROCESS
ELECTRO-CHEMICAL PROCESS

A process that causes the deposition or formation of a seal or coating of a chemical element or compound by the use of electricity.

ELECTRO-MAGNETIC FORCES
ELECTRO-MAGNETIC FORCES

Forces resulting from electrical charges that either attract or repel particles. Particles with opposite charges are attracted to each other. For example, a particle with positive charges is attracted to a particle with negative charges. Particles with similar charges repel each other. A particle with positive charges is repelled by a particle with positive charges and a particle with negative charges is repelled by another particle with negative charges.

ELECTROLYSIS (ELECT-TROLLEY-sis)
ELECTROLYSIS

The decomposition of material by an electric current.

ELECTROLYTE (ELECT-tro-LIGHT)
ELECTROLYTE

A substance which dissociates (separates) into two or more ions when it is dissolved in water.

ELECTROLYTIC PROCESS (ELECT-tro-LIT-ick)
ELECTROLYTIC PROCESS

A process that causes the decomposition of a chemical compound by the use of electricity.

ELECTRON
ELECTRON

An extremely small (microscopic), negatively charged particle. An electron is much too small to be seen with a microscope.

ELEMENT
ELEMENT

A substance which cannot be separated into substances of other kinds by ordinary chemical means. For example, sodium (Na) is an element.

ELUTRIATION (e-LOO-tree-A-shun)
ELUTRIATION

The washing of digested sludge in plant effluent. The objective is to remove (wash out) fine particulates and/or alkalinity in sludge. This process reduces the demand for conditioning chemicals and improves settling or filtering characteristics of the solids.

EMULSION (e-MULL-shun)
EMULSION

A liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid held in suspension in the other.

END POINT
END POINT

Samples are titrated to the end point. This means that a chemical is added, drop by drop, to a sample until a certain color change (blue to clear, for example) occurs which is called the *END POINT* of the titration. In addition to a color change, an end point may be reached by the formation of a precipitate or the reaching of a specified pH. An end point may be detected by the use of an electronic device such as a pH meter.

ENDOGENOUS (en-DODGE-en-us) ENDOGENOUS

A reduced level of respiration (breathing) in which organisms break down compounds within their own cells to produce the oxygen they need.

ENERGY GRADE LINE (EGL) ENERGY GRADE LINE (EGL)

A line that represents the elevation of energy head (in feet) of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel.

ENTERIC ENTERIC

Intestinal.

ENZYMES (EN-zimes) ENZYMES

Enzymes are organic substances which are produced by living organisms and speed up chemical changes.

EQUALIZING BASIN EQUALIZING BASIN

A holding basin in which variations in flow and composition of liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit. Also called a balancing reservoir.

ESTUARIES (ES-chew-wear-eez) ESTUARIES

Bodies of water which are located at the lower end of a river and are subject to tidal fluctuations.

EVAPOTRANSPIRATION (e-VAP-o-trans-spi-RAY-shun) EVAPOTRANSPIRATION

The total water removed from an area by transpiration (plants) and by evaporation from soil, snow and water surfaces.

EXPLOSIMETER EXPLOSIMETER

An instrument used to detect explosive atmospheres. When the **L**ower **E**xplosive **L**imit (L.E.L.) of an atmosphere is exceeded, an alarm signal on the instrument is activated.

F/M RATIO F/M RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg}/L \times 8.34\text{ lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg}/L \times 8.34\text{ lbs/gal}}$$

$$\text{or} \quad = \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

FACULTATIVE (FACK-ul-TAY-tive) FACULTATIVE

Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, facultative bacteria can live under aerobic or anaerobic conditions.

FACULTATIVE POND (FACK-ul-TAY-tive) FACULTATIVE POND

The most common type of pond in current use. The upper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.

FILAMENTOUS BACTERIA (FILL-a-MEN-tuss) FILAMENTOUS BACTERIA

Organisms that grow in a thread or filamentous form. Common types are thiothrix and actinomycetes.

FILTER AID FILTER AID

A chemical (usually a polymer) added to water to help remove fine colloidal suspended solids.

FIXED FIXED

A sample is "fixed" in the field by adding chemicals that prevent the water quality indicators of interest in the sample from changing before final measurements are performed later in the lab.

FIXED SPRAY NOZZLE FIXED SPRAY NOZZLE

Cone-shaped spray nozzle used to distribute wastewater over the filter media, similar to a lawn sprinkling system. A deflector or steel ball is mounted within the cone to spread the flow of wastewater through the cone, thus causing a spraying action. Also see DISTRIBUTOR.

FLAME POLISHED

FLAME POLISHED

Melted by a flame to smooth out irregularities. Sharp or broken edges of glass (such as the end of a glass tube) are rotated in a flame until the edge melts slightly and becomes smooth.

FLIGHTS

FLIGHTS

Scraper boards, made from redwood or other rot-resistant woods or plastic, used to collect and move settled sludge or floating scum.

FLOC

FLOC

Groups or clumps of bacteria and particles that have come together and formed a cluster. Found in aeration tanks and secondary clarifiers.

FLOCCULATION (FLOCK-you-LAY-shun)

FLOCCULATION

The gathering together of fine particles to form larger particles.

FLOW-EQUALIZATION SYSTEM

FLOW-EQUALIZATION SYSTEM

A device or tank designed to hold back or store a portion of peak flows for release during low-flow periods.

FOOD/MICROORGANISM RATIO

FOOD/MICROORGANISM RATIO

Food to microorganism ratio. A measure of food provided to bacteria in an aeration tank.

$$\frac{\text{Food}}{\text{Microorganisms}} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

$$= \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\text{ lbs/gal}}{\text{Volume, MG} \times \text{MLVSS, mg/}L \times 8.34\text{ lbs/gal}}$$

$$\text{or} \quad = \frac{\text{BOD, kg/day}}{\text{MLVSS, kg}}$$

Commonly abbreviated F/M Ratio.

FORCE MAIN

FORCE MAIN

A pipe that conveys wastewater under pressure from the discharge side of a pump to a point of gravity flow.

FREE AVAILABLE CHLORINE

FREE AVAILABLE CHLORINE

The amount of chlorine available in water. This chlorine may be in the form of dissolved gas (Cl_2), hypochlorous acid (HOCl), or hypochlorite ion (OCl^-), but does not include chlorine combined with an amine (ammonia or nitrogen) or other organic compound.

FREE AVAILABLE RESIDUAL CHLORINE

FREE AVAILABLE RESIDUAL CHLORINE

That portion of the total residual chlorine remaining in water or wastewater at the end of a specified contact period. Residual chlorine will react chemically and biologically as hypochlorous acid (HOCl) or hypochlorite ion (OCl^-).

FREE CHLORINE

FREE CHLORINE

Free chlorine is chlorine (Cl_2) in a liquid or gaseous form. Free chlorine combines with water to form hypochlorous (HOCl) and hydrochloric (HCl) acids. In wastewater free chlorine usually combines with an amine (ammonia or nitrogen) or other organic compounds to form combined chlorine compounds.

FREE OXYGEN

FREE OXYGEN

Molecular oxygen available for respiration by organisms. Molecular oxygen is the oxygen molecule, O_2, that is not combined with another element to form a compound.

FREE RESIDUAL CHLORINATION

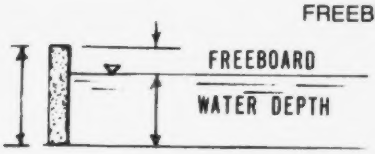
FREE RESIDUAL CHLORINATION

The application of chlorine or chlorine compounds to water or wastewater to produce a free available chlorine residual directly or through the destruction of ammonia (NH_3) or certain organic nitrogenous compounds.

FREEBOARD

FREEBOARD

The vertical distance from the normal water surface to the top of the confining wall.



FRICTION LOSS

FRICTION LOSS

The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.

GASIFICATION (GAS-i-fi-KAY-shun) GASIFICATION

The conversion of soluble and suspended organic materials into gas during anaerobic decomposition. In clarifiers the resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface. In anaerobic sludge digesters, this gas is collected for fuel or disposed of using the waste gas burner.

GRAB SAMPLE GRAB SAMPLE

A single sample of wastewater taken at neither a set time nor flow.

GRAVIMETRIC GRAVIMETRIC

A means of measuring unknown concentrations of water quality indicators in a sample by *WEIGHING* a precipitate or residue of the sample.

GRIT GRIT

The heavy mineral material present in wastewater, such as sand, eggshells, gravel, and cinders.

GRIT REMOVAL GRIT REMOVAL

Grit removal is accomplished by providing an enlarged channel or chamber which causes the flow velocity to be reduced and allows the heavier grit to settle to the bottom of the channel where it can be removed.

GROWTH RATE GROWTH RATE

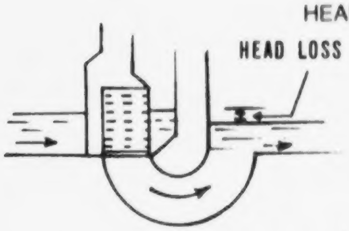
An experimentally determined constant to estimate the unit growth rate of bacteria while degrading organic wastes.

HEAD HEAD

A term used to describe the height or energy of water above a point. A head of water may be measured in either height (feet or meters) or pressure (pounds per square inch or kilograms per square centimeter). Also see DISCHARGE HEAD, DYNAMIC HEAD, STATIC HEAD, SUCTION HEAD, SUCTION LIFT and VELOCITY HEAD.

HEAD LOSS HEAD LOSS

An indirect measure of loss of energy or pressure. Flowing water will lose some of its energy when it passes through a pipe, bar screen, comminutor, filter or other obstruction. The amount of energy or pressure lost is called "head loss." Head loss is measured as the difference in elevation between the upstream water surface and the downstream water surface and may be expressed in feet or meters.



HEADER HEADER

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "manifold."

HEADWORKS HEADWORKS

The facilities where wastewater enters a wastewater treatment plant. The headworks may consist of bar screens, comminutors, a wet well and pumps.

HEPATITIS HEPATITIS

Hepatitis is an acute viral infection of the liver. Yellow jaundice is one symptom of hepatitis.

HUMUS SLUDGE HUMUS SLUDGE

The sloughed particles of biomass from trickling filter media that are removed from the water being treated in secondary clarifiers.

HYDRAULIC GRADE LINE (HGL) HYDRAULIC GRADE LINE (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. To reduce the release of odors from wastewater, the water surface should be kept as smooth as possible.

HYDRAULIC LOADING HYDRAULIC LOADING

Hydraulic loading refers to the flows (MGD or cu m/day) to a treatment plant or treatment process. Detention times, surface loadings and weir overflow rates are directly influenced by flows.

HYDROGEN ION CONCENTRATION (H^+) HYDROGEN ION CONCENTRATION (H^+)

The weight of hydrogen ion in moles per liter of solution. Commonly expressed as the pH value, which is the logarithm of the reciprocal of the hydrogen-ion concentration.

$$pH = \log \frac{1}{(H^+)}$$

HYDROGEN SULFIDE (H_2S) HYDROGEN SULFIDE (H_2S)

Hydrogen sulfide is a gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls your sense of smell so that you don't notice it after you have been around it for a while and because the odor is not noticeable in high concentrations. The gas is very poisonous to your respiratory system, explosive, flammable and colorless.

HYDROLOGIC CYCLE (HI-dro-loj-ic) HYDROLOGIC CYCLE

The process of evaporation of water into the air and its return to earth by precipitation (rain or snow). This process also includes transpiration from plants, groundwater movement and runoff into rivers, streams and the ocean.

HYDROLYSIS (hi-DROL-e-sis) HYDROLYSIS

The addition of water to the molecule to break down complex substances into simpler ones.

HYDROSTATIC SYSTEM HYDROSTATIC SYSTEM

In a hydrostatic sludge removal system, the surface of the water in the clarifier is higher than the surface of the water in the sludge well or hopper. This difference in pressure head forces sludge from the bottom of the clarifier to flow through pipes to the sludge well or hopper.

HYGROSCOPIC (HI-grow-SKOP-ic) HYGROSCOPIC

A substance that absorbs or attracts moisture from the air.

HYPOCHLORINATION (hi-poe-KLOR-i-NAY-shun) HYPOCHLORINATION

The application of hypochlorite compounds to water or wastewater for the purpose of disinfection.

HYPOCHLORINATORS (hi-poe-KLOR-i-NAY-tors) HYPOCHLORINATORS

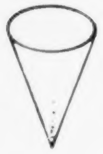
Chlorine pumps or devices used to feed chlorine solutions made from hypochlorites such as bleach (sodium hypochlorite) or calcium hypochlorite.

HYPOCHLORITE (hi-poe-KLOR-ite) HYPOCHLORITE

Hypochlorite compounds contain chlorine and are used for disinfection. They are available as liquids or solids (powder, granules, and pellets) in barrels, drums, and cans.

IMHOFF CONE IMHOFF CONE

A clear, cone-shaped container marked with graduations. The cone is used to measure the volume of settleable solids in a specific volume of wastewater.



IMPELLER IMPELLER

A rotating set of vanes designed to impel rotation of a mass of fluid.

IMPELLER PUMP IMPELLER PUMP

Any pump in which the water is moved by the continuous application of power from some mechanical source.

INCINERATION INCINERATION

The conversion of dewatered sludge cake by combustion (burning) to ash, carbon dioxide and water vapor.

INDICATOR (CHEMICAL) INDICATOR (CHEMICAL)

A substance that gives a visible change, usually of color, at a desired point in a chemical reaction, generally at a specified end point.

INDOLE (IN-dole) INDOLE

An organic compound (C_8H_7N) containing nitrogen which has an ammonia odor.

INFILTRATION (IN-fill-TRAY-shun) INFILTRATION

The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.

INFLOW INFLOW

Water discharged into the sewer system from sources other than regular connections. This includes flow from yard drains, foundation drains and around manhole covers. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.

INFLUENT (IN-flu-ent) INFLUENT

Wastewater or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process, or treatment plant.

INHIBITORY SUBSTANCES
INHIBITORY SUBSTANCES

Materials that kill or restrict the ability of organisms to treat wastes.

INOCULATE (in-NOCK-you-late)
INOCULATE

To introduce a seed culture into a system.

INORGANIC WASTE
INORGANIC WASTE

Waste material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Inorganic wastes are chemical substances of mineral origin; whereas organic wastes are chemical substances usually of animal or plant origin. Also see NONVOLATILE MATTER.

INTERFACE
INTERFACE

The common boundary layer between two fluids such as a gas (air) and a liquid (water) or a liquid (water) and another liquid (oil).

IONIC CONCENTRATION
IONIC CONCENTRATION

The concentration of any ion in solution, generally expressed in moles per liter.

IONIZATION
IONIZATION

The process of adding electrons to, or removing electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, and nuclear radiation can cause ionization.

JAR TEST
JAR TEST

A laboratory procedure that simulates coagulation/flocculation with differing chemical doses. The purpose of the procedure is to *ESTIMATE* the minimum coagulant dose required to achieve certain water quality goals. Samples of water to be treated are placed in six jars. Various amounts of chemicals are added to each jar, stirred and the settling of solids is observed. The lowest dose of chemicals that provides satisfactory settling is the dose used to treat the water.

JOULE (jewel)
JOULE

A measure of energy, work or quantity of heat. One joule is the work done when the point of application of a force of one newton is displaced a distance of one meter in the direction of the force.

KJELDAHL NITROGEN (KELL-doll)
KJELDAHL NITROGEN

Organic and ammonia nitrogen.

LAUNDERS (LAWN-ders)
LAUNDERS

Sedimentation tank effluent troughs.

LIMIT SWITCH
LIMIT SWITCH

A device that regulates or controls the travel distance of a chain or cable.

LINEAL (LIN-e-al)
LINEAL

The length in one direction of a line. For example, a board 12 feet long has 12 lineal feet in its length.

LIQUEFACTION (LICK-we-FACK-shun)
LIQUEFACTION

The conversion of large solid particles of sludge into very fine particles which either dissolve or remain suspended in wastewater.

LOADING
LOADING

Quantity of material applied to a device at one time.

M or MOLAR
M or MOLAR

A molar solution consists of one gram molecular weight of a compound dissolved in enough water to make one liter of solution. A gram molecular weight is the molecular weight of a compound in grams. For example, the molecular weight of sulfuric acid (H_2SO_4) is 98. A 1*M* solution of sulfuric acid would consist of 98 grams of H_2SO_4 dissolved in enough distilled water to make one liter of solution.

MBAS
MBAS

Methylene **B**lue **A**ctive **S**ubstance. Another name for surfactants, or surface active agents, is methylene blue active substances. The determination of surfactants is accomplished by measuring the color change in a standard solution of methylene blue dye.

MPN (EM-PEA-EN)
MPN

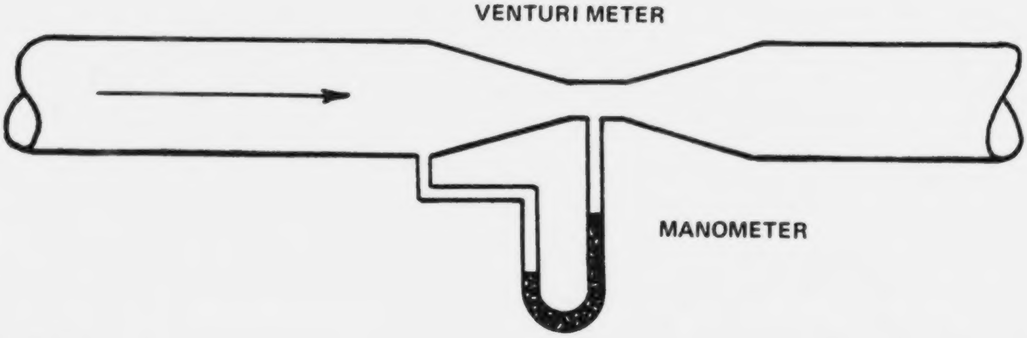
MPN is the **M**ost **P**robable **N**umber of coliform-group organisms per unit volume. Expressed as a density or population of organisms per 100 ml.

MANIFOLD MANIFOLD

A large pipe to which the ends of a series of smaller pipes are connected. Also called a "header."

MANOMETER (man-NAH-met-ter) MANOMETER

An instrument for measuring pressure. Usually a glass tube filled with a liquid and used to measure the difference in pressure across a flow-measuring device such as an orifice or Venturi meter. The instrument used to measure blood pressure is a type of manometer.



MASKING AGENTS MASKING AGENTS

Substances used to cover up or disguise unpleasant odors. Liquid masking agents are dripped into the wastewater, sprayed into the air, or evaporated (using heat) with the unpleasant fumes or odors and then discharged into the air by blowers to make an undesirable odor less noticeable.

MEAN CELL RESIDENCE TIME (MCRT) MEAN CELL RESIDENCE TIME (MCRT)

An expression of the average time that a microorganism will spend in the activated sludge process.

$$\text{MCRT, days} = \frac{\text{Solids in Activated Sludge Process, lbs}}{\text{Solids Removed from Process, lbs/day}}$$

MECHANICAL AERATION MECHANICAL AERATION

The use of machinery to mix air and water so that oxygen can be absorbed into the water. Some examples are: paddle wheels, mixers, or rotating brushes to agitate the surface of an aeration tank; pumps to create fountains; and pumps to discharge water down a series of steps forming falls or cascades.

MEDIA MEDIA

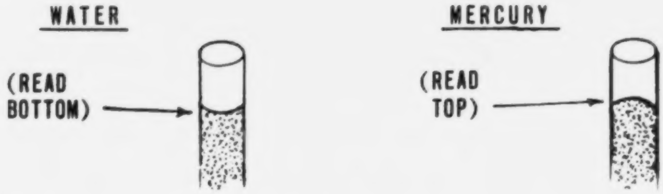
The material in a trickling filter on which slime organisms grow. As settled wastewater trickles over the media, slime organisms remove certain types of wastes thereby partially treating the wastewater. Also the material in a rotating biological contactor or in a gravity or pressure filter.

MEDIAN MEDIAN

The middle measurement or value. When several measurements are ranked by magnitude (largest to smallest), half of the measurements will be larger and half will be smaller.

MENISCUS (meh-NIS-cuss) MENISCUS

The curved top of a column of liquid (water, oil, mercury) in a small tube. When the liquid wets the sides of the container (as with water), the curve forms a valley. When the confining sides are not wetted (as with mercury), the curve forms a hill or upward bulge.



MERCAPTANS (mer-CAP-tans) MERCAPTANS

Compounds containing sulfur which have an extremely offensive skunk odor.

MESOPHILIC BACTERIA (mess-O-FILL-lick) MESOPHILIC BACTERIA

Medium temperature bacteria. A group of bacteria that grow and thrive in a moderate temperature range between 68°F (20°C) and 113°F (45°C). The optimum temperature range for these bacteria in anaerobic digestion is 85°F (30°C) to 100°F (38°C).

MICRON (MY-kron) MICRON

A unit of length. One millionth of a meter or one thousandth of a millimeter. One micron equals 0.00004 of an inch.

MICROORGANISMS (micro-ORGAN-is-sums) MICROORGANISMS

Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

MICROSCREEN MICROSCREEN

A device with a fabric straining media with openings usually between 20 and 60 microns. The fabric is wrapped around the outside of a rotating drum. Wastewater enters the open end of the drum and flows out through the rotating screen cloth. At the highest point of the drum the collected solids are backwashed by high-pressure water jets into a trough located within the drum.

MILLIGRAMS PER LITER, mg/*L* (MILL-i-GRAMS per LEET-er) MILLIGRAMS PER LITER, mg/*L*

A measure of the concentration by weight of a substance per unit volume. For practical purposes, one mg/*L* is equal to one part per million parts (ppm). Thus a liter of water with a specific gravity of 1.0 weighs one million milligrams; and if it contains 10 milligrams of dissolved oxygen, the concentration is 10 milligrams per million milligrams, or 10 milligrams per liter (10 mg/*L*), or 10 parts of oxygen per million parts of water, or 10 parts per million (10 ppm).

MILLIMICRON (MILL-e-MY-cron) MILLIMICRON

One thousandth of a micron or a millionth of a millimeter.

MIXED LIQUOR MIXED LIQUOR

When the activated sludge in an aeration tank is mixed with primary effluent or the raw wastewater and return sludge, this mixture is then referred to as mixed liquor as long as it is in the aeration tank. Mixed liquor also may refer to the contents of mixed aerobic or anaerobic digesters.

MIXED LIQUOR SUSPENDED SOLIDS (MLSS) MIXED LIQUOR SUSPENDED SOLIDS(MLSS)

Suspended solids in the mixed liquor of an aeration tank.

MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS) MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)

The organic or volatile suspended solids in the mixed liquor of an aeration tank.

MOLECULAR OXYGEN MOLECULAR OXYGEN

The oxygen molecule, O_2, that is not combined with another element to form a compound.

MOLECULAR WEIGHT MOLECULAR WEIGHT

The molecular weight of a compound in grams is the sum of the atomic weights of the elements in the compound. The molecular weight of sulfuric acid (H_2SO_4) in grams is 98.

Element	Atomic Weight	Number of Atoms	Molecular Weight
H	1	2	2
S	32	1	32
O	16	4	64
			98

MOLECULE (MOLL-uh-kule) MOLECULE

A molecule is the smallest portion of an element or compound that still retains or exhibits all the properties of the substance.

MOTILE (MO-till) MOTILE

Motile organisms exhibit or are capable of movement.

MOVING AVERAGE MOVING AVERAGE

To calculate the moving average for the last 7 days, add up values for the last 7 days and divide by 7. Each day add the most recent day to the sum of values and subtract the oldest value. By using the 7-day moving average, each day of the week is always represented in the calculations.

MUFFLE FURNACE MUFFLE FURNACE

A small oven capable of reaching temperatures up to 600°C. Muffle furnaces are used in laboratories for burning or incinerating samples to determine the amounts of volatile solids and/or fixed solids in samples of wastewater.

MULTI-STAGE PUMP MULTI-STAGE PUMP

A pump that has more than one impeller. A single-stage pump has one impeller.

N or NORMAL N or NORMAL

A normal solution contains one gram equivalent weight of a reactant (compound) per liter of solution. The equivalent weight of an acid is that weight which contains one gram atom of ionizable hydrogen or its chemical equivalent. For example, the equivalent weight of sulfuric acid (H_2SO_4) is 49 (98 divided by 2 because there are two replaceable hydrogen ions). A 1 *N* solution of sulfuric acid would consist of 49 grams of H_2SO_4 dissolved in enough water to make one liter of solution.

NPDES PERMIT NPDES PERMIT

National **P**ollutant **D**ischarge **E**limination **S**ystem permit is the regulatory agency document issued by either a federal or state agency which is designed to control all discharges of pollutants from point sources into U.S. waterways. NPDES permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal treatment plants, large agricultural feed lots and return irrigation flows.

NEUTRALIZATION (new-trall-i-ZAY-shun) NEUTRALIZATION

Addition of an acid or alkali (base) to a liquid to cause the pH of the liquid to move towards a neutral pH of 7.0.

NITRIFICATION (NYE-tri-fi-KAY-shun) NITRIFICATION

A process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the "nitrification stage" (first-stage BOD is called the "carbonaceous stage").

NITRIFYING BACTERIA NITRIFYING BACTERIA

Bacteria that change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).

NITROGENOUS (nye-TROG-en-ous) NITROGENOUS

Nitrogenous compounds contain nitrogen.

NOMOGRAM NOMOGRAM

A chart or diagram containing three or more scales used to solve problems with three or more variables instead of using mathematical formulas.

NONCORRODIBLE NONCORRODIBLE

A material that resists corrosion and will not be eaten away by wastewater or chemicals in wastewater.

NONSPARKING TOOLS NONSPARKING TOOLS

These tools will not produce a spark during use.

NONVOLATILE MATTER NONVOLATILE MATTER

Material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Volatile materials are chemical substances usually of animal or vegetable origin. Also see INORGANIC WASTE.

NUTRIENT CYCLE NUTRIENT CYCLE

The transformation or change of a nutrient from one form to another until the nutrient has returned to the original form, thus completing the cycle. The cycle may take place under either aerobic or anaerobic conditions.

NUTRIENTS NUTRIENTS

Substances which are required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen and phosphorus. Nitrogen and phosphorus are difficult to remove from wastewater by conventional treatment processes because they are water soluble and tend to recycle. Also see NUTRIENT CYCLE.

O & M MANUAL (**O**peration and **M**aintenance Manual) O & M MANUAL

A manual which outlines procedures for operators to follow to operate and maintain a specific wastewater treatment plant and the equipment in the plant.

OSHA OSHA

The Williams-Steiger **O**ccupational **S**afety and **H**ealth **A**ct of 1970 (OSHA) is a law designed to protect the health and safety of industrial workers and treatment plant operators. It regulates the design, construction, operation and maintenance of industrial plants and wastewater treatment plants. The Act does not apply directly to municipalities, *EXCEPT* in those states that have approved plans and have asserted jurisdiction under Section 18 of the OSHA Act. However, wastewater treatment plants have come under stricter regulation in all phases of activity as a result of OSHA standards. OSHA also refers to the federal and state agencies which administer the OSHA regulations.

OBLIGATE AEROBES OBLIGATE AEROBES

Bacteria that must have molecular (dissolved) oxygen (DO) to reproduce.

ODOR PANEL ODOR PANEL

A group of people used to measure odors.

OFFSET OFFSET

The difference between the actual value and the desired value (or set point) characteristic of proportional controllers that do not incorporate reset action. Also called DROOP.

OLFACTOMETER (ol-FACT-tom-meter) OLFACTOMETER

A device used to measure odors in the field by diluting odors with odor-free air.

ORGANIC WASTE ORGANIC WASTE

Waste material which comes mainly from animal or plant sources. Organic waste generally can be consumed by bacteria and other small organisms. Inorganic wastes are chemical substances of mineral origin.

ORGANISM ORGANISM

Any form of animal or plant life. Also see BACTERIA.

ORIFICE (OR-uh-fiss) ORIFICE

An opening in a plate, wall or partition. In a trickling filter distributor, the wastewater passes through an orifice to the surface of the filter media. An orifice flange set in a pipe consists of a slot or hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be related to flow in the pipe.

ORTHOTOLIDINE (or-tho-TOL-i-dine) ORTHOTOLIDINE

Orthotolidine is a colorimetric indicator of chlorine residual. If chlorine is present, a yellow-colored compound is produced. This method is no longer approved for tests of effluent chlorine residual.

OVERFLOW RATE OVERFLOW RATE

One of the guidelines for the design of settling tanks and clarifiers in treatment plants.

$$\text{Overflow Rate, gpd/sq ft} = \frac{\text{Flow, gallons/day}}{\text{Surface Area, sq ft}}$$

OXIDATION (ox-i-DAY-shun) OXIDATION

Oxidation is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances. The opposite of REDUCTION.

OXIDATION-REDUCTION POTENTIAL OXIDATION-REDUCTION POTENTIAL

The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant) and used as a qualitative measure of the state of oxidation in wastewater treatment systems.

OXIDIZED ORGANICS OXIDIZED ORGANICS

Organic materials that have been broken down in a biological process. Examples of these materials are carbohydrates and proteins that are broken down to simple sugars.

OXIDIZING AGENT OXIDIZING AGENT

An oxidizing agent is any substance, such as oxygen (O_2) and chlorine (Cl_2), that can add (take on) electrons. When oxygen or chlorine is added to wastewater, organic substances are oxidized. These oxidized organic substances are more stable and less likely to give off odors or to contain disease bacteria. The opposite of REDUCING AGENT.

OZONIZATION (O-zoe-nie-ZAY-shun) OZONIZATION

The application of ozone to water, wastewater, or air, generally for the purposes of disinfection or odor control.

PACKAGE TREATMENT PLANT PACKAGE TREATMENT PLANT

A small wastewater treatment plant often fabricated at the manufacturer's factory, hauled to the site, and installed as one facility. The package may be either a small primary or a secondary wastewater treatment plant.

PARALLEL OPERATION PARALLEL OPERATION

When wastewater being treated is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit. Also see SERIES OPERATION.

PARASITIC BACTERIA (PAIR-a-SIT-tick) PARASITIC BACTERIA

Parasitic bacteria are those bacteria which normally live off another living organism, known as the "host."

PATHOGENIC ORGANISMS (path-o-JEN-nick) PATHOGENIC ORGANISMS

Bacteria, viruses or cysts which can cause disease (typhoid, cholera, dysentery). There are many types of bacteria which do *NOT* cause disease and which are *NOT* called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.

PERCENT SATURATION PERCENT SATURATION

The amount of a substance that is dissolved in a solution compared with the amount that could be dissolved in the solution, expressed as a percent.

$$\text{Percent Saturation, \%} = \frac{\text{Amount of Sub. that is Dissolved} \times 100\%}{\text{Amount that Could be Dissolved in Solution}}$$

PERCOLATION (PURR-ko-LAY-shun) PERCOLATION

The movement or flow of water through soil or rocks.

PERISTALTIC PUMP (peri-STALL-tick) PERISTALTIC PUMP

A type of positive displacement pump.

pH (PEA-A-ch) pH

pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.

$$pH = \text{Log}\ \frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is most acid, 14 most basic, and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.

PHENOL (FEE-noll) PHENOL

An organic compound that is a derivative of benzene.

PHENOLPHTHALEIN ALKALINITY PHENOLPHTHALEIN ALKALINITY

A measure of the hydroxide ions plus one half of the normal carbonate ions in aqueous suspension. Measured by the amount of sulfuric acid required to bring the water to a pH value of 8.3, as indicated by a change in color of phenolphthalein. It is expressed in milligrams per liter of calcium carbonate.

PHOTOSYNTHESIS (foto-SIN-the-sis) PHOTOSYNTHESIS

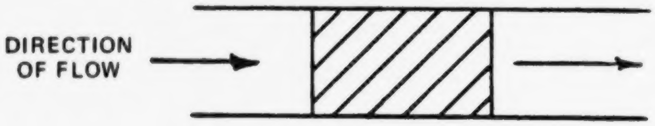
A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. All green plants grow by this process.

PHYSICAL WASTE TREATMENT PROCESS PHYSICAL WASTE TREATMENT PROCESS

Physical waste treatment processes include use of racks, screens, comminutors, and clarifiers (sedimentation and flotation). Chemical or biological reactions are not an important part of a physical treatment process.

PLUG FLOW PLUG FLOW

A type of flow that occurs in tanks, basins or reactors when a slug of wastewater moves through a tank without ever dispersing or mixing with the rest of the wastewater flowing through the tank.



PLUG FLOW

POLLUTION POLLUTION

Any change in the natural state of water which interferes with its beneficial reuse or causes failure to meet water-quality requirements.

POLYELECTROLYTE (POLY-electro-light) POLYELECTROLYTE

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a "polymer."

POLYMER (POLY-mer) POLYMER

A chemical formed by the union of many monomers (a molecule of low molecular weight). Polymers are used with other chemical coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. All polyelectrolytes are polymers, but not all polymers are polyelectrolytes.

POLYSACCHARIDE (polly-SAC-a-ride) POLYSACCHARIDE

A carbohydrate such as starch, insulin or cellulose.

PONDING PONDING

A condition occurring on trickling filters when the hollow spaces (voids) become plugged to the extent that water passage through the filter is inadequate. Ponding may be the result of excessive slime growths, trash, or media breakdown.

POPULATION EQUIVALENT POPULATION EQUIVALENT

A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pounds of oxygen per day for each person using the system (as measured by the standard BOD test).

$$\text{Pop. Equiv., persons} = \frac{\text{Flow, MGD} \times \text{BOD, mg/}L \times 8.34\ \text{lbs/gal}}{0.2\ \text{lbs BOD/day/person}}$$

POSTCHLORINATION POSTCHLORINATION

The addition of chlorine to the plant discharge or effluent, *FOLLOWING* plant treatment, for disinfection purposes.

POTABLE WATER (POE-ta-bl) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered safe for domestic consumption.

PRE-AERATION PRE-AERATION

The addition of air at the initial stages of treatment to freshen the wastewater, remove gases, add oxygen, promote flotation of grease, and aid coagulation.

PRECHLORINATION PRECHLORINATION

The addition of chlorine at the headworks of the plant *PRIOR TO* other treatment processes mainly for odor and corrosion control. Also applied to aid disinfection, to reduce plant BOD load, to aid in settling, to control foaming in Imhoff units and to help remove oil.

PRECIPITATE (pre-SIP-i-TATE) PRECIPITATE

To separate (a substance) out in solid form from a solution, as by the use of a reagent. The substance precipitated.

PRECOAT PRECOAT

Application of a free-draining, non-cohesive material such as diatomaceous earth to a filtering media. Precoating reduces the frequency of media washing and facilitates cake discharge.

PRETREATMENT PRETREATMENT

The removal of metal, rocks, rags, sand, eggshells, and similar materials which may hinder the operation of a treatment plant. Pretreatment is accomplished by using equipment such as racks, bar screens, comminutors, and grit removal systems.

PRIMARY TREATMENT PRIMARY TREATMENT

A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

PROCESS VARIABLE PROCESS VARIABLE

A physical or chemical quantity which is usually measured and controlled.

PROTEINACEOUS (PRO-ten-NAY-shus) PROTEINACEOUS

Materials containing proteins which are organic compounds containing nitrogen.

PROTOZOA (pro-toe-ZOE-ah) PROTOZOA

A group of microscopic animals (usually single-celled) that sometimes cluster into colonies.

PRUSSIAN BLUE PRUSSIAN BLUE

A paste or liquid used to show a contact area. Used to determine if gate valve seats fit properly.

PSYCHROPHILIC BACTERIA (sy-kro-FILL-lick) PSYCHROPHILIC BACTERIA

Cold temperature bacteria. A group of bacteria that grow and thrive in temperatures below 68°F (20°C).

PURGE PURGE

To remove a gas or vapor from a vessel, reactor or confined space.

PUTREFACTION (PEW-tree-FACK-shun) PUTREFACTION

Biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions.

PUTRESCIBLE (pew-TRES-uh-bull) PUTRESCIBLE

Material that will decompose under anaerobic conditions and produce nuisance odors.

PYROMETER (pie-ROM-uh-ter) PYROMETER

An apparatus used to measure high temperatures.

RACK RACK

Evenly spaced parallel metal bars or rods located in the influent channel to remove rags, rocks, and cans from wastewater.

RAW WASTEWATER RAW WASTEWATER

Plant influent or wastewater before any treatment.

REAGENT (re-A-gent) REAGENT

A substance which takes part in a chemical reaction and is used to measure, detect, or examine other substances.

RECALCINE (re-CAL-seen) RECALCINE

A lime-recovery process in which the calcium carbonate in sludge is converted to lime by heating at 1800°F (980°C).

RECARBONATION (re-CAR-bun-NAY-shun) RECARBONATION

A process in which carbon dioxide is bubbled through the water being treated to lower the pH.

RECEIVING WATER RECEIVING WATER

A stream, river, lake or ocean into which treated or untreated wastewater is discharged.

RECHARGE RATE RECHARGE RATE

Rate at which water is added beneath the ground surface to replenish or recharge groundwater.

RECIRCULATION RECIRCULATION

The return of part of the effluent from a treatment process to the incoming flow.

REDUCING AGENT REDUCING AGENT

A reducing agent is any substance, such as the chloride ion (Cl^-) and sulfide ion (S^{-2}), that can give up electrons. The opposite of OXIDIZING AGENT.

REDUCTION (re-DUCK-shun) REDUCTION

Reduction is the addition of hydrogen, removal of oxygen, or the addition of electrons to an element or compound. Under anaerobic conditions in wastewater, sulfate compounds or elemental sulfur are reduced to odor-producing hydrogen sulfide (H_2S) or the sulfide ion (S^{-2}). The opposite of OXIDATION.

RELIQUEFACTION (re-LICK-we-FACK-shun) RELIQUEFACTION

The return of a gas to a liquid. For example, a condensation of chlorine gas returning to the liquid form.

REFRACTORY MATERIALS (re-FRACK-tory) REFRACTORY MATERIALS

Material difficult to remove entirely from wastewater such as nutrients, color, taste- and odor-producing substances and some toxic materials.

REPRESENTATIVE SAMPLE REPRESENTATIVE SAMPLE

A portion of material or water identical in content to that in the larger body of material or water being sampled.

RESIDUAL CHLORINE RESIDUAL CHLORINE

Residual chlorine is the amount of chlorine remaining after a given contact time and under specific conditions.

RESPIRATION RESPIRATION

The process in which an organism uses oxygen for its life processes and gives off carbon dioxide.

RETENTION TIME RETENTION TIME

The time water, sludge or solids are retained or held in a clarifier or sedimentation tank. See DETENTION TIME.

RIPRAP RIPRAP

Broken stones, boulders, or other materials placed compactly or irregularly on levees or dikes for the protection of earth surfaces against the erosive action of waves.

RISING SLUDGE RISING SLUDGE

Rising sludge occurs in the secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.

ROTAMETER ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or a bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.

ROTARY PUMP ROTARY PUMP

A type of displacement pump consisting essentially of elements rotating in a pump case which they closely fit. The rotation of these elements alternately draws in and discharges the water being pumped. Such pumps act with neither suction nor discharge valves, operate at almost any speed, and do not depend on centrifugal forces to lift the water.

ROTIFERS (ROE-ti-fers) ROTIFERS

Microscopic animals characterized by short hairs on their front end.

SAR (**S**odium **A**dsorption **R**atio) SAR

This ratio expresses the relative activity of sodium ions in the exchange reactions with soil. The ratio is defined as follows:

$$\text{SAR} = \frac{\text{Na}}{\left[\frac{1}{2}(\text{Ca} + \text{Mg})\right]^{1/2}}$$

where Na, Ca, and Mg are concentrations of the respective ions in milliequivalents per liter of water.

$$\text{Na, meq}/L = \frac{\text{Na, mg}/L}{23.0\ \text{mg/meq}} \qquad \text{Ca, meq}/L = \frac{\text{Ca, mg}/L}{20.0\ \text{mg/meq}}$$

$$\text{Mg, meq}/L = \frac{\text{Mg, mg}/L}{12.15\ \text{mg/meq}}$$

SCFM SCFM

Cubic **F**eet of air per **M**inute at **S**tandard conditions of temperature and pressure.

SVI (Sludge Volume Index) SVI

This is a test used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared with its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.

$$\text{SVI} = \frac{\text{Wet Settled Sludge, ml} \times 1000}{\text{Dried Sludge Solids, mg}}$$

SANITARY SEWER (SAN-eh-tare-ee SUE-er) SANITARY SEWER

A sewer intended to carry wastewater from homes, businesses, and industries. Storm water runoff should be collected and transported in a separate system of pipes.

SAPROPHYTIC ORGANISMS (SAP-pro-FIT-tik) SAPROPHYTIC ORGANISMS

Organisms living on dead or decaying organic matter. They help natural decomposition of the organic solids in wastewater.

SCREEN SCREEN

A device used to retain or remove suspended or floating objects in wastewater. The screen has openings that are generally uniform in size. It retains or removes objects larger than the openings. A screen may consist of bars, rods, wires, gratings, wire mesh, or perforated plates.

SEALING WATER SEALING WATER

Water used to prevent wastewater or dirt from reaching moving parts. Sealing water is at a higher pressure than the wastewater it is keeping out of a mechanical device.

SECCHI DISC (SECK-key) SECCHI DISC

A flat, white disc lowered into the water by a rope until it is just barely visible. At this point, the depth of the disc from the water surface is the recorded secchi disc reading.

SECONDARY TREATMENT SECONDARY TREATMENT

A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

SEED SLUDGE SEED SLUDGE

In wastewater treatment, seed, seed culture or seed sludge refers to a mass of sludge which contains very concentrated populations of microorganisms. When a seed sludge is mixed with the wastewater or sludge being treated, the process of biological decomposition takes place more rapidly.

SEIZING SEIZING

Seizing occurs when an engine overheats and a component expands so the engine will not run. Also called "freezing."

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SEPTICITY (sep-TIS-it-tee) SEPTICITY

Septicity is the condition in which organic matter decomposes to form foul-smelling products associated with the absence of free oxygen. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.

SERIES OPERATION SERIES OPERATION

When wastewater being treated flows through one treatment unit and then flows through another similar treatment unit. Also see PARALLEL OPERATION.

SET POINT SET POINT

The position at which the control or controller is set. This is the same as the desired value of the process variable.

SEWAGE SEWAGE

The used water and solids from homes that flow to a treatment plant. The preferred term is wastewater.

SHEAR PIN SHEAR PIN

A straight pin with a groove around the middle that will weaken the pin and cause it to fail when a certain load or stress is exceeded. The purpose of the pin is to protect equipment from damage due to excessive loads or stresses.

SHOCK LOAD SHOCK LOAD

The arrival at a plant of a waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and sloughing off of the growth or slime on the trickling-filter media. Organic or hydraulic overloads also can cause a shock load.

SHORT-CIRCUITING SHORT-CIRCUITING

A condition that occurs in tanks or ponds when some of the water or wastewater travels faster than the rest of the flowing water.

SHREDDING SHREDDING

Comminution. A mechanical treatment process which cuts large pieces of wastes into smaller pieces so they won't plug pipes or damage equipment. *SHREDDING* and *COMMINUTION* usually mean the same thing.

SIDESTREAM SIDESTREAM

Wastewater flows that develop from other storage or treatment facilities. This wastewater may or may not need additional treatment.

SIGNIFICANT FIGURE SIGNIFICANT FIGURE

The number of accurate numbers in a measurement. If the distance between two points is measured to the nearest hundredth and recorded as 238.41 feet, the measurement has five significant figures.

SINGLE-STAGE PUMP SINGLE-STAGE PUMP

A pump that has only one impeller. A multi-stage pump has more than one impeller.

SKATOLE (SKATE-tole) SKATOLE

An organic compound (C_9H_9N) containing nitrogen which has a fecal odor.

SLAKE SLAKE

To become mixed with water so that a true chemical reaction takes place, such as in the slaking of lime.

SLOUGHINGS (SLUFF-ings) SLOUGHINGS

Trickling-filter slimes that have been washed off the filter media. They are generally quite high in BOD and will lower effluent quality unless removed.

SLUDGE (sluj) SLUDGE

The settleable solids separated from liquids during processing or the deposits of foreign materials on the bottoms of streams or other bodies of water.

SLUDGE AGE SLUDGE AGE

A measure of the length of time a particle of suspended solids has been undergoing aeration in the activated sludge process.

$$\text{Sludge Age, days} = \frac{\text{Suspended Solids Under Aeration, lbs or kg}}{\text{Suspended Solids Added, lbs/day or kg/day}}$$

SLUDGE DENSITY INDEX (SDI) SLUDGE DENSITY INDEX (SDI)

This test is used in a way similar to the Sludge Volume Index (SVI) to indicate the settleability of a sludge in a secondary clarifier or effluent. SDI = 100/SVI. Also see SLUDGE VOLUME INDEX (SVI).

SLUDGE DIGESTION SLUDGE DIGESTION

The process of changing organic matter in sludge into a gas or a liquid or a more stable solid form. These changes take place as microorganisms feed on sludge in anaerobic (more common) or aerobic digesters.

SLUDGE GASIFICATION SLUDGE GASIFICATION

A process in which soluble and suspended organic matter are converted into gas by anaerobic decomposition. The resulting gas bubbles can become attached to the settled sludge and cause large clumps of sludge to rise and float on the water surface.

SLUDGE VOLUME INDEX (SVI) SLUDGE VOLUME INDEX (SVI)

This is a test used to indicate the settling ability of activated sludge (aerated solids) in the secondary clarifier. The test is a measure of the volume of sludge compared with its weight. Allow the sludge sample from the aeration tank to settle for 30 minutes. Then calculate SVI by dividing the volume (ml) of wet settled sludge by the weight (mg) of that sludge after it has been dried. Sludge with an SVI of one hundred or greater will not settle as readily as desirable because it is as light as or lighter than water.

$$\text{SVI} = \frac{\text{Wet Settled Sludge, ml} \times 1000}{\text{Dried Sludge Solids, mg}}$$

SLUDGE-VOLUME RATIO (SVR) SLUDGE-VOLUME RATIO (SVR)

The volume of sludge blanket divided by the daily volume of sludge pumped from the thickener.

SLUGS SLUGS

Intermittent releases or discharges of industrial wastes.

SLURRY (SLUR-e) SLURRY

A thin watery mud or any substance resembling it (such as a grit slurry or a lime slurry).

SODIUM ADSORPTION RATIO (SAR) SODIUM ABSORPTION RATIO (SAR)

This ratio expresses the relative activity of sodium ions in the exchange reactions with soil. The ratio is defined as follows:

$$\text{SAR} = \frac{\text{Na}}{[\tfrac{1}{2}(\text{Ca} + \text{Mg})]^{1/2}}$$

where Na, Ca, and Mg are concentrations of the respective ions in milliequivalents per liter of water.

$$\text{Na, meq}/L = \frac{\text{Na, mg}/L}{23.0\ \text{mg/meq}} \qquad \text{Ca, meq}/L = \frac{\text{Ca, mg}/L}{20.0\ \text{mg/meq}}$$

$$\text{Mg, meq}/L = \frac{\text{Mg, mg}/L}{12.15\ \text{mg/meq}}$$

SOLUBLE BOD SOLUBLE BOD

Soluble BOD is the BOD of water that has been filtered in the standard suspended solids test.

SOLUTE SOLUTE

The substance dissolved in a solution. A solution is made up of the solvent and the solute.

SOLUTION SOLUTION

A liquid mixture of dissolved substances. In a solution it is impossible to see all the separate parts.

SPECIFIC GRAVITY SPECIFIC GRAVITY

Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles usually have a specific gravity of 0.5 to 2.5.

SPLASH PAD SPLASH PAD

A structure made of concrete or other durable material to protect bare soil from erosion by splashing or falling water.

STABILIZE STABILIZE

To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.

STABILIZED WASTE STABILIZED WASTE

A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

STANDARD SOLUTION STANDARD SOLUTION

A solution in which the exact concentration of a chemical or compound is known.

STANDARDIZE STANDARDIZE

(1) To compare with a standard. In wet chemistry, to find out the exact strength of a solution by comparing with a standard of known strength. This information is used to adjust the strength by adding more water or more of the substance dissolved. (2) To compare an instrument or device with a standard. This helps you to adjust the instrument so that it reads accurately or to prepare a scale, graph or chart that is accurate.

STASIS (STAY-sis) STASIS

Stagnation or inactivity of the life processes within organisms.

STATIC HEAD STATIC HEAD

When water is not moving, the distance (in feet or meters) from a point to the water surface.

STATOR STATOR

That portion of a machine which contains the stationary (non-moving) parts that surround the moving parts.

STEP-FEED AERATION STEP-FEED AERATION

Step-feed aeration is a modification of the conventional activated sludge process. In step aeration, primary effluent enters the aeration tank at several points along the length of the tank, rather than all of the primary effluent entering at the beginning or head of the tank and flowing through the entire tank.

STERILIZATION (star-uh-luh-ZAY-shun) STERILIZATION

The removal or destruction of all living microorganisms, including pathogenic and saprophytic bacteria, vegetative forms and spores. Compare with DISINFECTION.

STETHOSCOPE STETHOSCOPE

An instrument used to magnify sounds and convey them to the ear.

STOP LOG STOP LOG

A log or board in an outlet box or device used to control the water level in ponds.

STORM SEWER STORM SEWER

A separate sewer that carries runoff from storms, surface drainage, and street wash, but does not include domestic and industrial wastes.

STRIPPED GASES STRIPPED GASES

Gases that are released from a liquid by bubbling air through the liquid or by allowing the liquid to be sprayed or tumbled over media.

STRIPPED ODORS STRIPPED ODORS

Odors that are released from a liquid by bubbling air through the liquid or by allowing the liquid to be sprayed and/or tumbled over media.

STUCK STUCK

Not working. A stuck digester does not decompose organic matter properly. The digester is characterized by low gas production, high volatile acid to alkalinity relationship, and poor liquid-solids separation. A digester in a stuck condition is sometimes called a "sour" or "upset" digester.

SUCTION HEAD SUCTION HEAD

The pressure (in feet (meters) or pounds per square inch (kilograms per square centimeter)) on the suction side of a pump. The pressure can be measured from the center line of the pump *UP TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUCTION LIFT SUCTION LIFT

The *NEGATIVE* pressure (in feet (meters) or inches (centimeters) of mercury vacuum) on the suction side of the pump. The pressure can be measured from the center line of the pump *DOWN TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUPERNATANT (sue-per-NAY-tent) SUPERNATANT

Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or to the primary clarifier.

SURFACE LOADING SURFACE LOADING

Surface loading is calculated by dividing the flow into a sedimentation tank or a clarifier by the surface area of the unit.

$$\text{Surface Loading, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Surface Area, sq ft}}$$

SURFACTANT SURFACTANT

Abbreviation for surface-active agent. The active agent in detergents that possesses a high cleaning ability.

SUSPENDED SOLIDS SUSPENDED SOLIDS

(1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in *STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER* and referred to as nonfilterable residue.

TOC TOC

Total **O**rganic **C**arbon. TOC measures the amount of organic carbon in water.

TERTIARY TREATMENT (TER-she-AIR-ee) TERTIARY TREATMENT

Any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. May include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration. Also called ADVANCED WASTE TREATMENT.

THERMOPHILIC BACTERIA (thermo-FILL-lick) THERMOPHILIC BACTERIA

Hot temperature bacteria. A group of bacteria that grow and thrive in temperatures above 113°F (45°C). The optimum temperature range for these bacteria in anaerobic decomposition is 120°F (49°C) to 135°F (57°C).

THIEF HOLE THIEF HOLE

A digester sampling well.

THRESHOLD ODOR THRESHOLD ODOR

The minimum odor of a sample (gas or water) that can just be detected after successive odorless (gas or water) dilutions.

TIME LAG TIME LAG

The time required for processes and control systems to respond to a signal or to reach a desired level.

TITRATE (TIE-trate) TITRATE

To *TITRATE* a sample, a chemical solution of known strength is added on a drop-by-drop basis until a color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical solution to completion of the reaction as signaled by the end point.

TOTAL DYNAMIC HEAD (TDH) TOTAL DYNAMIC HEAD (TDH)

When a pump is lifting or pumping water, the vertical distance (in feet or meters) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TOTAL RESIDUAL CHLORINE TOTAL RESIDUAL CHLORINE

The amount of chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine. Also see RESIDUAL CHLORINE.

TOTALIZER TOTALIZER

A device that continuously sums or adds the flow into a plant in gallons or million gallons or some other unit of measurement.

TOXIC (TOX-ick) TOXIC

Poisonous.

TOXICITY (tox-IS-it-tee) TOXICITY

A condition which may exist in wastes and will inhibit or destroy the growth or function of certain organisms.

TRANSPIRATION (TRAN-spear-RAY-shun) TRANSPIRATION

The process by which water vapor is lost to the atmosphere from living plants.

TRICKLING FILTER TRICKLING FILTER

A treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water treated.

TRICKLING-FILTER MEDIA TRICKLING-FILTER MEDIA

Rocks or other durable materials that make up the body of the filter. Synthetic (manufactured) media have been used successfully.

TRUNK SEWER TRUNK SEWER

A sewer that receives wastewater from many tributary branches or sewers and serves a large territory and contributing population.

TURBID TURBID

Having a cloudy or muddy appearance.

TURBIDITY METER TURBIDITY METER

An instrument for measuring the amount of particles suspended in water. Precise measurements are made by measuring how light is scattered by the suspended particles. The normal measuring range is 0 to 100 and is expressed as Nephelometric Turbidity Units (NTU's).

TURBIDITY UNITS TURBIDITY UNITS

Turbidity units, if measured by nephelometric (reflected light) instrumental procedure, are expressed in nephelometric turbidity units (NTU). Those turbidity units obtained by other instrumental methods or visual methods are expressed in Jackson Turbidity Units (JTU) and sometimes as Formazin Turbidity Units (FTU). The FTU nomenclature comes from the Formazin polymer used to prepare the turbidity standards for instrument calibration. Turbidity units are a measure of the cloudiness of water.

TWO-STAGE FILTERS TWO-STAGE FILTERS

Two filters are used. Effluent from the first filter goes to the second filter, either directly or after passing through a clarifier.

ULTRAFILTRATION ULTRAFILTRATION

A membrane filtration process used for the removal of organic compounds in an aqueous (watery) solution.

UPSET UPSET

An upset digester does not decompose organic matter properly. The digester is characterized by low gas production, high volatile acid/alkalinity relationship, and poor liquid-solids separation. A digester in an upset condition is sometimes called a "sour" or "stuck" digester.

VELOCITY HEAD VELOCITY HEAD

A vertical height (in feet or meters) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

VOLATILE (VOL-a-til) VOLATILE

A volatile substance is one that is capable of being evaporated or changed to a vapor at relatively low temperatures.

VOLATILE ACIDS VOLATILE ACIDS

Acids produced during digestion. Fatty acids which are soluble in water and can be steam-distilled at atmospheric pressure. Also called "organic acids." Volatile acids are commonly reported as equivalent to acetic acid.

VOLATILE LIQUIDS VOLATILE LIQUIDS

Liquids which easily vaporize or evaporate at room temperature.

VOLATILE SOLIDS VOLATILE SOLIDS

Those solids in water, wastewater, or other liquids that are lost on ignition of the dry solids at 550°C.

VOLUMETRIC VOLUMETRIC

A means of measuring unknown concentrations of water quality indicators in a sample *BY DETERMINING THE VOLUME* of titrant or liquid reagent needed to complete particular reactions.

VOLUTE (vol-LOOT) VOLUTE

The spiral-shaped casing which surrounds a pump, blower, or turbine impeller and collects the liquid or gas discharged by the impeller.

WASTEWATER WASTEWATER

The used water and solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also may be included in the wastewater that enters a plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WATER HAMMER WATER HAMMER

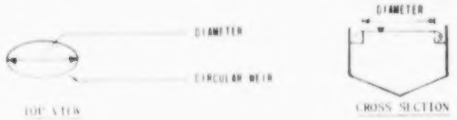
The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can do serious damage to the system.

WEIR (weer) WEIR

(1) A wall or plate placed in an open channel and used to measure the flow. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

WEIR DIAMETER (weer) WEIR DIAMETER

Many circular clarifiers have a circular weir within the outside edge of the clarifier. All the water leaving the clarifier flows over this weir. The diameter of the weir is the length of a line from one edge of a weir to the opposite edge and passing through the center of the circle formed by the weir.



WEIR, PROPORTIONAL (weer) WEIR, PROPORTIONAL

A specially shaped weir in which the flow through the weir is directly proportional to the head.

WET OXIDATION WET OXIDATION

A method of treating or conditioning sludge before the water is removed. Compressed air is blown into the liquid sludge. The air and sludge mixture is fed into a pressure vessel where the organic material is stabilized. The stabilized organic material and inert (inorganic) solids are then separated from the pressure vessel effluent by dewatering in lagoons or by mechanical means.

WET WELL WET WELL

A compartment or room in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

Y, GROWTH RATE Y, GROWTH RATE

An experimentally determined constant to estimate the unit growth rate of bacteria while degrading organic wastes.

ZOOGLEAL FILM (ZOE-glee-al) ZOOGLEAL FILM

A complex population of organisms that form a "slime growth" on the trickling-filter media and break down the organic matter in wastewater. These slimes consist of living organisms feeding on the wastes in wastewater, dead organisms, silt, and other debris. "Slime growth" is a more common word.

ZOOGLEAL MASS (ZOE-glee-al) ZOOGLEAL MASS

Jelly-like masses of bacteria found in both the trickling filter and activated sludge processes. These masses may be formed for or function as the protection against predators and for storage of food supplies. Also see BIOMASS.

SUBJECT INDEX

VOLUME I

A

- Abnormal operation
  - activated sludge, 249
  - aerated grit chambers, 86
  - chlorination, 345
  - chlorinators, 345, 346, 348
  - grit channels, 84
  - oxidation ditches, 260, 261
  - ponds, 291
  - primary treatment, 116
  - rotating biological contactors, 216
  - sedimentation, 116
  - sulfonator, 386
  - trickling filters, 174
- Activated carbon, dechlorination, 376
- Activated sludge
  - Also see Package aeration plants and Chapter 11 and Chapter 2, *ADVANCED WASTE TREATMENT*
  - abnormal operation, 249
  - aeration methods, 245
  - aeration tank, 44, 239
  - aerobic digestion, 241
  - bulking, 249
  - centrifuge tests, 239
  - chlorination, 249
  - clarifiers, 128, 132, 234, 239, 249, 250
  - cold weather, 249
  - complete mix, 244, 245
  - contact stabilization, 244, 245
  - contact time, 234, 239, 250
  - control of process, 239, 240
  - conventional activated sludge, 228
    - also see Chapter 11
  - description, 42, 234
  - diffusers, 245, 247, 265
  - dissolved oxygen, 239
  - efficiency of process, 240
  - effluent, 239, 240, 248, 249
  - energy use, 265
  - extended aeration, 241, 244
  - flow diagram, 35, 237, 238
  - foam, 248, 249
  - food/microorganism ratio, 234, 255
  - housekeeping, 249, 251
  - hydraulic loading, 239, 240, 249
  - influent, 234, 240
  - industrial waste treatment, 228, 240, 265
    - also see Chapter 2, *INDUSTRIAL WASTE TREATMENT*
  - inspecting new facilities, 245
  - layout, 35, 236, 238, 244
  - maintenance, 245, 248, 251, 265
  - mass, 239
  - mechanical aeration, 245, 246
  - microorganisms, 234, 235, 239, 240, 249
  - mixed liquor suspended solids, 241, 245, 250
  - mixing, 239
  - odors, 239, 248, 249
  - operation, 240, 248, 265
  - operational strategy, 240, 249
  - organisms, 239, 240
  - oxidation, 234
  - oxidation ditch, 252
  - oxygen requirements, 239, 240
  - package plants, 42, 241
  - plans and specifications, 265
  - pretreatment requirements, 234, 239
  - pure oxygen, 228
    - also see Chapter 2, *ADVANCED WASTE TREATMENT*
  - purpose, 234, 241
  - recordkeeping, 245, 248, 250
  - removal efficiencies, 42
  - removal of sludge, 43
  - return sludge, 132, 248, 249
  - safety, 240, 250
  - sampling, 250
  - secondary clarifiers, 234, 239, 249, 250
  - settleability tests, 239, 250
  - shutdown, 249
  - sludge age, 241
  - sludge blanket, 239
  - sludge pumps, 128
  - sludge removal, 128
  - sludge wasting, 43, 132, 239, 241, 248, 250
  - solids, 132, 239
  - stabilize, 234
  - start up, 245, 248
  - storm flows, 249
  - temperature, 249
  - toxic wastes, 240, 249
  - trend chart, 250
  - troubleshooting, 249
  - types of processes, 241
  - visual inspection, 248, 250
  - wasting sludge, 43, 132, 239, 241, 248, 250
  - zoogleal bacteria, 234
- Advanced waste treatment, 37, 49
- Aerated grit chamber, 84
- Aerated pond, 291
- Aeration systems, activated sludge, 43, 245
- Aeration tank appearance, activated sludge, 248, 250
- Aeration tanks, activated sludge, 44, 239
- Aerobic digestion
  - also see Chapter 12
  - description, 45, 241
  - package plant, 241
  - sludge disposal, 51
  - sludge handling, 45
- Aerobic ponds, 45
- Aerobic process
  - activated sludge, 42, 225

  ponds, 273
  rotating biological contactor, 42, 195
  trickling filter, 42, 153
Agglomerate, 239
Air flotation, 134
Air gap, 344
Air-lift pumps, 241
Air padding, 356
Algae, 21, 279
Alkalinity test
  see Chapter 16
Ambient temperature, 371
Amoebic dysentery, 329
Amperometric, 338
Anaerobic digester
  see Chapter 12
Anaerobic digestion
  also see Chapter 12
  description, 45
  mixing, 45
  sludge disposal, 50
  sludge handling, 45
Anaerobic ponds, 45, 282, 284, 285
Annual operating reports
  see Chapter 19
Ascaris (giant roundworm), 329
Axial flow pumps
  see Chapter 15

B

BOD, 39, 172
BOD, soluble, 208
Bacillary dysentery, 329
Bar screens
  automatic controls, 68
  cleaning methods, 62
  description, 37, 62
  disposal of screenings, 64, 68, 69
  failure, 64
  head loss, 64, 68
  layout, 65
  maintenance, 64, 68
  manually cleaned, 64, 66
  mechanically cleaned, 66, 67
  operation, 68
  operational strategy, 92
  parts, 67
  purpose, 67
  safety, 64, 67
  shutdown, 68
  start up, 68
  troubleshooting, 68
Barminutor
  description, 38, 76
  head loss, 76
  maintenance, 76
  operational strategy, 92
  parts, 76
  picture, 77-79
  purpose, 76
  safety, 76
  shutdown, 76
  start up, 76
  troubleshooting, 76
Batch feed, ponds, 284, 288, 291
Beds, sludge
  see Chapter 12
Belt drives, pump maintenance
  see Chapter 15
Biochemical oxygen demand, 39, 172
Biodegradable, 200
Bioflocculation, 286
Biological contactors
  abnormal operation, 216
  advantages, 208
  alkalinity, 212
  biomass, 211, 214
  bulkhead, 200, 212
  clarifiers, 200
  clearances, 211
  cold weather, 200
  contact time, 212
  covered, 200, 208, 220
  description, 200, 202, 203
  drive units, 208, 218, 219
  efficiency of process, 208, 212
  effluent, 208, 212, 214
  energy use, 208
  equalization tanks, 208, 214
  flow diagram, 201
  flow equalization tanks, 208, 214
  growth, 200, 214
  holding tanks, 200
  housekeeping, 217
  hydraulic balance, 211
  hydraulic loading, 208, 212, 220, 221
  influent, 212, 214
  industrial waste treatment, 212
  inspecting new contactors, 211
  layout, 205
  limitations, 208
  loadings, 220
  lubrication, 211, 216, 217
  maintenance, 208, 211, 216, 217
  media, 200, 203, 204, 214, 217
  metric calculations, 221, 222
  nitrogen removal, 208, 212, 220, 221
  odors, 214, 215, 216
  operation, 211
  operational strategy, 211
  organic loading, 208, 212, 214, 220, 221
  parts, 206
  performance, 212
  pH, 212
  plans and specifications, 220
  power outage, 216
  pretreatment requirements, 208
  purpose, 206
  recirculation, 211, 212, 214
  recordkeeping, 211
  rotation of media, 211
  safety, 211, 216, 220
  sampling, 212
  shutdown, 216
  slime growth, 200, 211, 214
  sloughing, 200, 211, 214, 216
  sludge deposits, 214
  speed of rotation, 211
  stages, 200
  start up, 208
  sulfur compounds 214
  supernatant treatment, 214
  temperature, 200, 211, 212, 220
  time of contact, 212
  toxic wastes, 214
  trend chart, 213
  troubleshooting, 211, 212, 215, 218
  underdrain, 206
  visual inspection, 211, 214, 215
Biological filter

  rotating biological contactor, 42
  trickling filter, 42
Biological growth
  rotating biological contactor, 200, 214
  trickling filter, 159
Biological process, effects of industrial wastes
  see Toxic wastes
Biological treatment, 30, 42
Biomass, rotating biological contactor, 211, 214
Blowers, activated sludge, 245
  also see Chapter 11
Bourdon tube
  see Chapter 8, *ADVANCED WASTE TREATMENT*
Breakout of chlorine, 350
Breakpoint chlorination, 333
Bubble pipe, level measurement
  see Chapter 15
Bulking
  also see Chapter 11
  sludge, 118
  toxic waste, 118

C

Carbon absorption, physical chemical treatment
  see Chapter 6, *INDUSTRIAL WASTE TREATMENT*
Carbon regeneration, physical chemical treatment
  see Chapter 6, *INDUSTRIAL WASTE TREATMENT*
Carbon usage, management
  see Chapter 6, *INDUSTRIAL WASTE TREATMENT*
Cathodic protection, 245, 386
Centrifugal pumps
  see Chapter 15
Centrifuges
  operation see Chapter 3, *ADVANCED WASTE TREATMENT*
  sludge dewatering, 45
Chemical characteristics, wastewater, 16
Chemical conditioning
  see Chapter 3, *ADVANCED WASTE TREATMENT*
Chemical feed, physical chemical treatment
  see Chapters 3 and 6, *INDUSTRIAL WASTE TREATMENT*
Chlorination
  abnormal operation, 345
  activated sludge, 375
  application points, 335, 336
  BOD reduction, 375
  baffles, 333
  breakout of chlorine, 350
  breakpoint, 333, 334
  chlorinator control, 338
  collection system, 336
  contact time, 333
  container storage, 345
  containers, 356
  control of process, 338
  corrosion control, 375
  description, 329
  diffusers, 342
  disinfection, 50, 349
  dosage, 335, 338
  emergency repair kits, 365
  evaporators, 345
  flow diagram, 330
  gas, 344
  grease, 375
  hypochlorination, 333, 341
  injectors, 344, 347
  leaks, 364
  liquid, 344
  measurement of residual, 342
  mixing, 333, 339, 342, 350
  nomogram, 339
  odor control, 349, 374
  operation, 345
  operational strategy, 349
  pH, 331, 333
  plans and specifications, 371, 374
  plant chlorination, 336
  points of application, 336
  postchlorination, 336
  prechlorination, 336
  process control, 338, 349
  protection of structures, 375
  purpose, 329
  reactions of chlorine, 331
  recordkeeping, 371
  repair kits, 365
  requirements, 333
  residual, 338
  safety, 354
    also see Chlorine safety
  sedimentation, 375
  short-circuiting, 333, 339, 350
  shutdown, 349
  solution lines, 342
  start up, 342, 344
  storage for containers, 345
  temperature, 333
  trickling filters, 169, 375
  troubleshooting, 350, 351, 352
  water supply, 344
Chlorinators
  abnormal operation, 345, 346, 348
  chlorine residual control, 338
  compound-loop control, 338
  connections, 362
  container storage, 345
  controls, 338, 367
  corrosion, 346
  description, 366
  dew point test, 344
  differences, 386
  electrolysis, 346
  evaporators, 344, 345, 366, 370
  filters, 366
  flow-proportional control, 338
  gas, 344
  injectors, 344, 347, 373
  installation, 371, 373
  leaks, 344, 364
  liquid, 344
  maintenance, 366, 371
  manual control, 338, 349
  moisture, 344
  operation, 345
  operational strategy, 349
  orifice, 366
  parts, 369
  piping, 323
  plans and specifications, 371, 374
  purpose, 366
  recordkeeping, 371
  residual control, 338, 347
  safety, 354
    also see Chlorine safety
  shutdown, 349
  start up, 342, 344
  start-stop control, 338
  step-rate control, 338
  storage of containers, 345
  temperature, 371

  timed-program control, 338
  troubleshooting, 346, 350, 351, 352
  vacuum system, 366, 368
  valves, 362, 373
  vent lines, 347
  ventilation, 371
  water supply, 344, 371, 373
Chlorine
  absorption solution, 365
  activated sludge, 375
  air padding, 356
  alarm systems, 365
  ammonia, 332
  application, 335
  BOD reduction, 375
  breakout, 350
  breakpoint, 333
  chloramines, 332
  chlorine dioxide, 332
  cleaning lines, 364
  connections, 362
  contact chamber, 350
  contact time, 333
  container storage, 345
  containers, 356
  corrosion control, 375
  cylinders, 356
  demand, 331
  diffusers, 342
  disinfection, 50, 331
  disposal, 365
  dosage, 335, 338
  emergency procedures, 355
  emergency repair kits, 365
  evaporators, 345, 366, 370
  first aid, 355
  free chlorine, 331
  fusible plug, 356
  gas, 344
  grease, 375
  handling, 356
  hypochlorite, 331
  injectors, 347
  leak detection, 365
  leaks, 355, 364
  liquid, 344
  manifolds, 373
  mixing, 333, 342
  odor control, 374
  pH, 333
  physiological response, 354
  piping, 373
  properties, 354
  protection of structures, 375
  protective clothing, 355
  railroad tank cars, 356, 362
  reactions, 331, 332
  recordkeeping, 371
  repair kits, 365
  residual, 333, 338, 342
  safety, 354
    also see Chlorine safety
  sedimentation, 375
  solution lines, 342
  tank cars, 356, 362
  temperature, 333, 371
  ton tanks, 356
  trickling filters, 375
  troubleshooting, 350
  valves, 362, 373
  ventilation, 371
  use, 331
  weigh, 371
Chlorine demand
  trickling filter, 174
  wastewater, 331
Chlorine dioxide
  disinfection, 331, 332
  facility, 371
  handling sodium chlorite, 371
  hazards, 371
  installation, 371
  layout, 371
  maintenance, 371
  pH, 332
  reactions, 332
  sodium chlorite, 371
  system parts, 371
  water treatment, 332
Chlorine measurement, 338, 342
Chlorine requirement, test, 331, 339
Chlorine residual, test, 331
Chlorine safety
  absorption solution, 365
  alarm systems, 365
  breathing apparatus, 355
  calibration of equipment, 354
  chlorine properties, 354
  cleaning lines, 364
  disposal, 365
  emergency procedures, 355
  emergency repair kits, 365
  equipment calibration, 354
  first aid, 354, 355
  fusible plug, 356
  handling chlorine, 356
  handling sodium chlorite, 371
  hazards, 354
  leak detection, 365
  leaks, 354, 355, 364
  physiological response, 354
  planning, 355
  program, 354
  protective clothing, 355
  railroad tank cars, 356, 362
  repair kits, 365
  rules, 354
  sodium chlorite, 371
  tank cars, 356, 362
  training, 354
Chlororganic, 332
Cholera, 18, 329
Clarifier
  drawing, 40, 41
  effluent, 106, 119
  influent, 119
  primary, 39, 106
  removal efficiencies, 39
  scum removal, 39
  secondary, 39, 43, 106
  sludge, 106
  sludge removal, 39
Clarity, 172
Classifier, grit, 87, 89
Closed impeller
  see Chapter 15
Coagulation, 135
Coarse screens, 62
Coliforms, 172
Collection system, 29

Collector mechanism, sludge
  start up, 114
  troubleshooting, 121
Colloids, 134
Combined sewers, 29
Comminutor
  description, 38, 69
  drawing, 71, 72, 73, 74
  head loss, 76
  mercury seal, 75
  operation, 76
  operational strategy, 92
  parts, 75
  purpose, 69, 75
  safety, 75, 76
  section view, 71, 72, 73, 74
  shutdown, 76
  start up, 76
  troubleshooting, 76
Community relations, management responsibilities, 6
Completed mixed system, activated sludge, 244, 245
Composite sample, 119, 212, 297
Conditioning sludge
  see Chapter 12 and Chapter 3, *ADVANCED WASTE TREATMENT*
Contact, chlorine disinfection, 333, 350
Contact stabilization, activated sludge, 244, 245
Control methods, activated sludge, 239, 240
Conventional activated sludge
  see Chapter 11
Conventional treatment, 49
Conversion units,
  see Appendix, A.10, 430
Covered activated sludge, oxygen activated sludge
  see Chapter 2, *ADVANCED WASTE TREATMENT*
Covers, anaerobic digester
  see Chapter 3, *ADVANCED WASTE TREATMENT*
Cycle
  natural purification, 1, 20
  nutrient, 20
Cyclone grit separators
  description, 86
  disposal, 89
  layout, 87
  maintenance, 89
  operation, 89
  parts, 89
  purpose, 86, 89
  section drawing, 88
  shutdown, 89
  start up, 89

D

DO, 172
DPD tests, 342
Data collection and laboratory control
  see Chapter 16
Dechlorination, 37, 50, 376
Density, 125
Detention time
  activated sludge clarifiers, 138
  aeration tanks, 234, 239
  calculation, 125
  definition, 39
  measurement, 126
  primary sedimentation, 39, 125
  trickling filter clarifiers, 128
Detritus, 91
Dew point test, 344
Dewatering, sludge, 45
Diaphragm bulb, level measurement
  see Chapter 15
Diffusers, activated sludge, 245, 247, 265
Digester cleaning, maintenance
  see Chapter 12
Digester gas
  see Chapter 12
Digestion
  aerobic, 45
  anaerobic, 45
Discharge permits, 21
Diseases, 329
Disinfection
  chlorine, 50
  chlorine dioxide, 371
  chlorine residual, 335
  effluent, 37, 50, 349
  flow diagram, 330
  importance, 331
  purpose, 329, 335
Disposal
  also see Chapter 13 and Chapters 3 and 7, *ADVANCED WASTE TREATMENT*
  effluent, 50
  grit, 38, 62, 82, 92
  screening, 37, 64, 69
  scum, 106
  sludge, 106
  solids, 45, 50
Dissolved air flotation, 134
  also see Chapter 3, *ADVANCED WASTE TREATMENT*
Dissolved oxygen
  activated sludge, 239
  ponds, 282, 284, 296, 297, 301
  rotating biological contactor, 212
  test, see Chapter 16
  trickling filter, 172
Dissolved solids, in wastewater, 19
Distribution, trickling filter, 159, 181, 187
Distributors, trickling filter, 159, 181, 187
Domestic wastes, 17
Domestic wastewater, characteristics, 17
Dosing tanks, trickling filter, 165, 166
Drying, sludge, 45
  also see Chapter 12
Duckweed, 290
Dysentery, 18, 329

E

Eductor, 341
Efficiency of processes
  activated sludge, 240
  oxidation ditch, 252, 257, 258, 260
  package aeration, 240
  ponds, 288, 296, 298
  primary treatment, 110
  rotating biological contactors, 208, 212
  sedimentation, 110
  trickling filters, 171
Effluent disposal, 50
Electric transmitters
  see Chapter 15 and Chapter 8, *ADVANCED WASTE TREATMENT*
Electrical safety
  see Chapter 14
Electrolysis, 346
Elutriation, sludge
  see Chapter 12 and Chapter 3, *ADVANCED WASTE TREATMENT*

Emergency planning
  see Chapter 19
Employment for operators, 1, 6, 7
Emulsions, 134
Enclosure, rotating biological contactor, 200, 208, 220
Energy
  activated sludge, 265
  oxidation ditches, 257, 265
  package aeration, 265
  ponds, 282
  rotating biological contactors, 208
  trickling filters, 165, 170, 173
Engines
  see Chapter 15
Enzymes, 333
Equalization tanks, 208
Erosion, ponds, 290, 300
Explosimeters, 93
Extended aeration, activated sludge, 241, 244

F

Facultative bacteria, 239
Facultative ponds, 49
Fecal coliform test
  see Chapter 16
Filamentous bacteria, 239, 375
Filamentous growth, bulking
  see Chapter 11
Filter press
  operation, see Chapter 22
  sludge dewatering, 45
Filter staging, trickling filter, 167, 168
Filters
  see Chapters 3 and 4, *ADVANCED WASTE TREATMENT*
Fire control, safety
  see Chapter 14
First aid program
  see Chapter 14
  chlorine, 355
  sulfur dioxide, 378
Flame trap, anaerobic digester
  see Chapter 12
Flies, trickling filter, 176
Flights, 114
Float mechanism, level measurement
  see Chapter 15
Floating covers, anaerobic digester
  see Chapter 12
Floating sludge
  see Chapter 11
Floc, 239
Flocculation, 135
Flotation
  also see Chapter 6, *INDUSTRIAL WASTE TREATMENT*
  chemical, 134
  description, 134
  dissolved air, 134
  pressure, 135
  purpose, 106
  vacuum, 135
Flow diagram
  activated sludge, 237, 238
  chlorination, 330
  chlorine dioxide, 382
  combined sedimentation-digestion unit, 136
  disinfection, 330
  oxidation ditch, 252, 253
  package aeration, 242, 243
  ponds, 282, 283
  pretreatment, 63
  primary treatment 107, 108
  rotating biological contactors, 201
  sedimentation, 107, 108
  trickling filters, 160
Flow equalization, 208
Flow measurement, 39
Flow meter, 39
Flow proportioning, sampling, 119, 212, 296
F:M ratio
  activated sludge, 255
  oxygen activated sludge
    see Chapter 2, *ADVANCED WASTE TREATMENT*
Foaming
  see Chapters 11 and 12
Food to microorganism ratio, 255

G

Gasification, 116
Giardiasis, 329
Glossary, 405
Grab sample, 212, 296
Grit
  aerated removal, 38
  chambers, 38
  channels, 38
  cleaning channels, 82
  cyclone removal, 86
  definition, 38, 80
  disposal, 38, 62, 92
  quantities, 90
  removal, 38, 80
  transport, 38
  washing, 38
Grit chambers, aerated
  abnormal operation, 86
  description, 84
  drawing, 85
  grit removal, 86
  operation, 86
  parts, 86
  purpose, 86
  shutdown, 86
  start up, 84
Grit channels
  abnormal operation, 84
  aerated grit chamber, 84
  cleaning, 82
  dead spots, 82
  deflector, 82
  description, 80
  disposal of grit, 82
  drawing, 81, 83, 85
  example problems, 82
  grit removal, 82
  maintenance, 84
  measuring velocity, 82
  operation, 84
  operational strategy, 82
  parts, 80
  plans and specifications, 93
  purpose, 80
  safety, 84
  shutdown, 84
  start up, 84
  troubleshooting, 82
  velocity, 80
Grit classifier, 87, 89
Grit washer
  description, 90
  maintenance, 90

  operation, 90
  parts, 90
  purpose, 90
  safety, 90
  section drawing, 91
  shutdown, 90
Groundwater recharge, wastewater, 50

H

Headworks, 38
Heat exchanger, anaerobic digester
  see Chapter 12
Hepatitis, 18, 329
Herbicides, 289
High rate
  anaerobic digesters
    see Chapter 12
  activated sludge
    see Chapter 11
  trickling filter, 167, 184
Housekeeping, 217, 249, 253, 288
Hydraulic loading
  activated sludge, 239, 240, 249
  clarifiers, 120, 121
  rotating biological contactors, 208, 212, 220, 221
  sedimentation, 120, 121
  trickling filters, 173, 184, 185
Hydraulic overloads
  see Operational strategy
Hydrogen sulfide
  collection systems, 29
  hazards, 18, 122
  problems, 18
Hydrogen sulfide removal, digester gas
  see Chapter 12
Hydrostatic system, 128
Hypochlorinators
  control, 341
  description, 341, 371
  eductors, 341
  emergency use, 349
  feed rate, 341
  flow meters, 341
  hypochlorite, 331, 371
  maintenance, 341
  piping, 341
  pH, 331
  purpose, 333
  safety, 333, 341
  storage, 341
  valves, 341
Hypochlorite, 331, 371

I

Icing
  oxidation ditch, 260
  trickling filter, 177
Imhoff cone, 19
Imhoff tank
  operation, 143
  process equipment, 143
  section, 143
Impacts of waste discharges
  algae, 21
  human health, 18
  nutrients, 18
  odors, 17
  oxygen depletion, 17
  pathogenic bacteria, 18
  sludge and scum, 17
  toxic substances, 18
Impellers, open and closed
  see Chapter 15
Incineration
  also see Chapter 3, *ADVANCED WASTE TREATMENT*
  description, 45
  sludge, 45
Industrial waste treatment
  also see Chapter 6, *INDUSTRIAL WASTE TREATMENT*
  activated sludge, 228, 240, 265
    also see Chapter 2, *ADVANCED WASTE TREATMENT*
  oxidation ditches, 257
  ponds, 299
  rotating biological contactors, 212
  trickling filters, 165, 178
Industrial wastes, 16
Industrial wastewater flows, 29
Infectious hepatitis, 18
Infiltration, 29, 177
Influent, 29
Inhibitory substances, 214
Inorganic compounds, in wastewater, 20
Inorganic wastes, 16
Insect control
  ponds, 288, 289
  trickling filters, 170, 176
Inspecting new facilities
  activated sludge, 245
  clarifiers, 114
  cyclone grit separator, 89
  grit channels, 84
  oxidation ditches, 255
  ponds, 287
  rotating biological contactors, 211
  sedimentation basins, 114
  trickling filters, 169

J

Jobs for operators, 1, 6, 7

K

Kjeldahl nitrogen
  see Chapter 16
Kraus process, activated sludge
  see Chapter 11

L

Laboratory
  see Chapter 16
Lagoons, 282
  see Ponds
Land disposal, effluent, 50, 282
Land treatment, 282
  also see Chapter 7, *ADVANCED WASTE TREATMENT*
Landfill, 51
Launders, 126
Lift station, 30
Lifting, safe practices
  see Chapter 14

M

MPN, 333
Magnetic meters
  see Chapter 15
Maintenance,
  also see Chapter 15 and Chapter 7, *INDUSTRIAL WASTE TREATMENT*

  activated sludge, 245, 248, 251, 265
  aerobic digestion
    see Chapter 12
  anaerobic digester
    see Chapter 12
  bar screens, 64
  barminutors, 76
  chlorinators, 366, 371
  chlorine dioxide, 371
  comminutors, 76
  cyclone grit separators, 89
  disinfection, 366, 371
  grit channels, 84
  grit washer, 90
  hypochlorinators, 341
  mechanically cleaned screens, 67
  oxidation ditch, 262, 265
  oxygen activated sludge
    see Chapter 2, *ADVANCED WASTE TREATMENT*
  package aeration, 245, 248, 251, 265
  ponds, 288, 290, 292, 294, 300
  primary treatment, 115, 122, 134
  pumps
    see Chapter 15
  racks, 64
  recordkeeping, 122
  rotating biological contactors, 208, 211, 216, 217
  sedimentation, 115, 122, 134
  sulfonator, 387
  surface aerators, 295
  trickling filters, 181
Manpower needs, 6
Masking agent, 141, 176
Mean cell residence time
  see Chapter 11
Media
  rotating biological contactor, 42, 200
  trickling filters, 42, 159, 162, 163, 164, 184
Median, 286
Mesophilic process, anaerobic digester
  see Chapter 12
Methane gas, 45
Metric conversion factors
  chlorination, 388
  dechlorination, 388
  preliminary treatment, 94
  primary treatment, 144
  rotating biological contactors, 221, 222
  sedimentation, 144
Metric problem solutions
  chlorination, 388
  dechlorination, 388
  oxidation ditches, 264
  ponds, 307, 309
  preliminary treatment, 93
  primary treatment, 144
  rotating biological contactors, 221, 222
  sedimentation, 144
  trickling filters, 185, 187
Microorganisms
  in wastewater, 329
  removal by treatment, 329
Mixed flow pumps
  see Chapter 15
Mixed liquor, 43
Mixing, anaerobic digestion, 45
Molecule, 125
Most probable number, 333
Multiple hearth incinerator
  see Chapter 3, *ADVANCED WASTE TREATMENT*

N

NPDES permits, 21, 333
National Pollutant Discharge Elimination System
  permits, 21, 333
National Safety Council, 61
Natural purification cycle, 1, 20
Nephelometry
  see Chapter 16
Neutralization, 214
Nitrification, 185, 212
Nitrogen
  cycle, 20
  test in wastewater
    see Chapter 16
Nomogram, chlorination control, 339, 340
Nuclear power plants, 17
Nutrient cycle, 20
Nutrient removal
  see *ADVANCED WASTE TREATMENT*

O

OSHA, 123
Objectves of operators, 23
Occupational safety and health act
  see Chapter 14
Odor
  activated sludge, 239, 248, 249
  chlorination, 374
  disinfection, 374
  masking, 141, 176
  oxidation ditch, 256, 257, 258, 260
  ponds, 279, 282, 284, 290-293
  rotating biological contactor, 214-216
  trickling filter, 176, 187
Odor control, 374
  also see Chapter 1, *ADVANCED WASTE TREATMENT*
Open impeller
  see Chapter 15
Operation
  activated sludge, 240, 248, 265
  bar screens, 68
  barminutors, 76
  chlorinators, 345
  comminutors, 69, 76
  cyclone grit separators, 89
  grit channels, 84
  grit washer, 90
  oxidation ditch, 257, 258, 262, 263
  package aeration, 248
  ponds, 288-290
  primary treatment, 115, 124, 132
  racks, 68
  rotating biological contactors, 211, 265
  sedimentation, 115, 124, 132
  sulfonators, 381, 386
  trickling filters, 165, 170, 173
Operation problems
  see Troubleshooting
Operational strategy
  activated sludge, 240, 249
  bar screens, 92
  barminutors, 92
  chlorination, 349
  comminutors, 92
  grit channels, 92
  hydraulic overloads, see process
  organic overloads, see process
  oxidation ditch, 249, 262
  package aeration, 249

  ponds, 292
  primary treatment, 115
  racks, 92
  rotating biological contactors, 211
  screens, 92
  sedimentation, 115
  sulfonator, 386
  trickling filters, 173
Operators
  jobs, 1, 6, 7
  objectives, 23
  salary, 1
Organic compounds in wastewater, 20
Organic overloads
  see Operational strategy
Overflow rate, weir, 126
Oxidation, 234
Oxidation ditches
  abnormal operation, 260, 261
  activated sludge, 255
  aeration basin, 252
  BOD loading, 252, 263
  bulking, 260
  bump start, 256
  chlorination, 256
  clarifiers, 256, 257, 260, 266
  cold weather, 252, 260, 266
  contact time, 255, 257, 260, 264, 266
  cover, 260
  description, 252
  dissolved oxygen, 256-258
  dimensions, 263
  ditch, 252, 258
  efficiency of process, 252, 257, 258, 260
  effluent, 252, 256, 258, 260, 266
  energy use, 257, 265
  F/M ratio, 255, 263
  floc, 255, 257
  flow diagram, 252, 253
  foam, 258
  food, 257
  food to microorganism ratio, 255, 263
  gear reducer, 258, 261, 262, 265
  housekeeping, 255, 258, 262
  hydraulic loading, 252, 260
  ice buildup, 260, 266
  industrial waste treatment, 257
  influent, 252, 257, 260, 263
  inspecting new facilities, 255
  layout, 253
  lining, 265
  loadings, 252, 255
  lubrication, 256, 262
  maintenance, 262, 265
  metric system, 264, 266
  microorganisms, 260
  mixed liquor, 252, 256, 257, 258, 260
  nitrogen removal, 260
  odors, 256-258, 260
  operation, 257, 259, 262, 263
  operational strategy, 249, 262
  organic loading, 252, 263
  oxygen, 257, 258
  parts, 252
  performance, 252, 257, 259
  pinpoint floc, 257
  plans and specifications, 255, 265
  power outage, 265, 266
  purpose, 252
  pumps, 256
  recordkeeping, 256-258
  return sludge, 252, 256, 257
  rotor, 252, 254-257, 260-262
  safety, 255, 265
  sampling, 256, 257
  scum, 252, 257
  secondary clarifiers, 257, 266
  seed activated sludge, 256
  settleability tests, 256
  settling tank, 252
  shock loads, 252
  shutdown, 260
  slingers, 262
  sludge age, 264
  solids, 257, 266
  start up, 255, 256
  temperature, 252, 260
  toxic wastes, 252, 257
  trend chart, 259
  troubleshooting, 258, 260
  velocity, 252, 255, 257, 258
  visual inspection, 256-258
  waste sludge, 252, 256-258
  weir, 256
Oxidation ponds, 49, 282
Oxidizing agent, 331
Oxygen activated sludge
  see Chapter 2, *ADVANCED WASTE TREATMENT*
Ozone
  disinfection
    see Chapter 1, *ADVANCED WASTE TREATMENT*
  odor control
    see Chapter 1, *ADVANCED WASTE TREATMENT*

P

Package aeration plants
  also see Activated sludge
  abnormal operation, 249
  aeration methods, 241, 245
  aerobic digestion, 241
  bulking, 249
  chlorination, 249
  clarifiers, 249, 250
  cold weather, 249
  complete mix, 244, 245
  contact stabilization, 244, 245
  contact time, 241, 250
  description, 241
  diffusers, 241, 245, 247, 265
  efficiency of process, 240
  effluent, 241, 248, 249
  energy use, 265
  extended aeration, 241, 244
  flow diagram, 242, 243
  foam, 248, 249
  housekeeping, 249, 251
  hydraulic loading, 249
  industrial waste treatment, 228, 240, 265
    also see Chapter 2, *INDUSTRIAL WASTE TREATMENT*
  influent, 234, 240
  inspecting new facilities, 245
  layout, 242-244
  maintenance, 245, 248, 251, 265
  mechanical aeration, 241, 245, 246
  microorganisms, 234, 235, 239, 240, 249
  mixed liquor suspended solids, 241, 245, 250
  odors, 248, 249
  operation, 248, 265
  operational strategy, 249
  parts, 242, 244

  plans and specifications, 265
  pretreatment requirements, 234, 239
  purpose, 241
  recordkeeping, 245, 248, 250
  return sludge, 248, 249
  safety, 250
  sampling, 250
  secondary clarifiers, 249, 250
  settleability tests, 239, 250
  shutdown, 249
  sludge age, 241
  start up, 245, 248
  storm flows, 249
  temperature, 249
  toxic wastes, 240, 249
  trend chart, 250
  troubleshooting, 249
  types of plants, 241
  visual inspection, 248, 250
  wasting sludge, 241, 248, 249, 250
Package treatment plant
  activated sludge, 241
  combined sedimentation-digestion unit, 136
  oxidation ditch, 252
Parallel operation
  ponds, 289
  trickling filters, 160
Parasites, 329
Paratyphoid, 329
Parshall flume, 39
Particle settling, 124
Particle size, primary sedimentation, 124
Pathogenic bacteria, 50, 329
Pay for operators, 1
Percolation, wastewater, 144, 286
Permits, effluent discharge, 21
Personal hygiene, 61
pH
  definition, 284
  ponds, 284, 287, 294, 295
  rotating biological contactors, 212
  test
    see Chapter 16
  trickling filter effluent, 172
pH effects
  ponds, 284
  rotating biological contactor, 212
pH measurement
  see Chapter 16
Phosphorus removal
  see Chapter 5, *ADVANCED WASTE TREATMENT*
Photosynthesis, 49, 284
Physical chemical treatment
  see Chapters 3 and 6, *INDUSTRIAL WASTE TREATMENT*
Physical treatment, 159
Physiological Response
  chlorine, 354
  sulfur dioxide, 378
Plans and specifications
  activated sludge, 265
  bar screens, 93
  chlorination, 371, 374
  chlorinators, 371, 374
  grit channels, 93
  oxidation ditch, 255, 265
  package aeration, 265
  ponds, 299
  primary treatment, 132
  racks, 93
  rotating biological contactors, 220
  screens, 93
  sedimentation, 132
  sulfonators, 371, 374
  trickling filters, 186
  wet wells, 93
Polio, 18, 329
Polishing ponds, 282
Pollution, 16
Polymer feed, operation
  see Chapter 4, *ADVANCED WASTE TREATMENT*
Ponding, trickling filter, 174, 179
Ponds
  abnormal operation, 291
  acid production, 284
  advantages, 282
  aerobic ponds, 282, 284, 285
  algae, 279, 287, 292, 301
  alkalinity, 296
  anaerobic ponds, 282, 284, 285
  arithmetic, 311
  BOD loading, 291, 292
  batch operation, 284, 288, 291
  bioflocculation, 286
  chlorination, 288, 291
  classification, 282, 283
  cleaning, 291, 292
  cold weather, 284, 287, 288, 291, 295, 308
  color, 287, 288, 292
  controlled discharge, 284, 286, 291
  cover, 290
  depth, 287, 289, 300
  description, 49, 279, 284
  detention time, 282, 284, 286, 287, 298, 305
  dissolved oxygen, 282, 284, 295, 296, 300
  efficiency of process, 286, 296, 298
  effluent, 282, 291, 292, 296, 297, 308
  energy use, 282
  facultative ponds, 282, 284, 286
  fencing, 305
  filamentous algae, 300
  flow diagram, 280, 281
  headworks, 290, 299
  herbicides, 289
  history, 279
  housekeeping, 288
  hydraulic loading, 291, 292, 305
  industrial waste treatment, 299
  influent, 296, 297
  insect control, 288
  inspecting new facilities, 287
  land, 282
  layout, 32, 280, 281
  levee maintenance, 290, 300
  limitations, 282
  loadings, 291, 292, 305
  maintenance, 288, 290, 292, 295, 300
  mechanical aeration, 282
  methane fermentation, 284
  metric calculations, 307, 309
  mosquito control, 295
  nutrients, 279, 286, 299
  odors, 279, 282, 284, 289-292
  operation, 288-290
  operational strategy, 292
  organic loading, 291, 292, 304
  oxidation ponds, 282
  parallel operation, 290
  parts, 279
  performance, 286, 295

  pH, 284, 287, 295, 296
  plans and specifications, 299
  polishing ponds, 282
  pond isolation, 308
  population loading, 305
  purpose, 279
  recirculation, 288, 290, 291, 300, 305
  recordkeeping, 295, 299, 317
  removal efficiencies, 296, 298
  safety, 298
  sampling, 295
  scum control, 288, 291
  series operation, 290
  short-circuiting, 300
  shutdown, 291
  signs, 300
  start up, 287
  surface aerators, 288, 292, 305
  temperature, 284, 287, 288, 291, 295, 296, 300
  toxic wastes, 286, 291, 299
  trend chart, 297
  troubleshooting, 288, 291, 298
  tules, 288, 305
  use of ponds, 279, 282
  visual inspection, 287, 288, 292, 295
  water hyacinth culture, 309
  weed control, 288, 289
Population equivalent, 306
Positive displacement pumps
  see Chapter 15
Power outage, 116, 216
Pre-aeration
  description, 92
  purpose, 92
Preliminary treatment, 30
Preserving samples
  see Chapter 16
Pretreatment
  activated sludge, 234, 239
  bar screens, 62
  barminutors, 76
  comminutors, 69
  cyclone grit separators, 86
  domestic wastes, 30, 37, 61
  grit removal, 80
  industrial wastes
    see Chapter 5 and 6, *INDUSTRIAL WASTE TREATMENT*
  pre-aeration, 92
  purpose, 61
  racks, 62
  rotating biological contactor, 208
Preventive maintenance
  see Chapter 15
Primary sedimentation
  definition, 39
  detention time, 39
Primary treatment
  abnormal operation, 116
  description, 30, 39, 106
  detention time, 125
  efficiency of process, 120, 127
  effluent, 119
  flow diagram, 107, 108
  hydraulic load, 121
  influent, 119
  maintenance, 115, 122, 134
  operation, 115, 124, 132
  operational strategy, 115
  overflow rate, 126
  parts, 109, 110, 112
  performance, 127
  plans and specifications, 132
  pumping, 121
  purpose, 106, 112
  recordkeeping, 122, 151
  safety, 114, 122, 134
  sampling, 119
  section, 109
  shutdown, 115
  sludge and scum pumping, 121
  solids loading, 127
  start up, 114
  surface loading, 126
  toxic wastes, 116, 118
  troubleshooting, 116, 117, 120
  weir overflow rate, 126
Process control
  see Operation and Operational strategy
Public relations, 6
Pump station, 30
Pumping
  scum, 121
  sludge, 121
Pumps
  see Chapter 15
Purification cycle, 1
Purpose of treatment process
  activated sludge, 234, 241
  bar screens, 67
  barminutors, 76
  chlorination, 329
  comminutors, 69, 75
  cyclone grit separators, 86, 89
  dechlorination, 37, 50, 376
  disinfection, 329, 335
  flotation, 106
  grit channels, 80
  grit washers, 90
  hypochlorindation, 333
  oxidation ditch, 252
  package aeration, 241
  ponds, 279
  pretreatment, 61
  primary treatment, 106, 112
  racks, 67
  rotating biological contactors, 206
  sedimentation, 106, 112
  trickling filters, 163
Pyrometer, 211

Q

Qualifications for operators, 5

R

Racks
  see Bar screens
Radioactive wastes, 17
Receiving waters
  algae, 21
  human health, 18
  nutrients, 18
  odors, 17
  oxygen depletion, 17
  pathogenic bacteria, 18
  sludge and scum, 17
  toxic substances, 18
Recharge, groundwater, 50

Recirculation
  ponds, 288, 290, 292, 300, 305
  rotating biological contactor, 211, 212, 214
  trickling filter, 165, 170, 172, 174, 183
Reclamation
  see Chapter 7, *ADVANCED WASTE TREATMENT*
Recordkeeping
  activated sludge, 245, 248, 250
  chlorination, 371
  chlorinators, 371
  oxidation ditch, 256-258
  package aeration, 245, 248, 250
  ponds, 295, 299, 317
  primary treatment, 151
  rotating biological contactors, 211
  sedimentation, 151
  sulfonator, 387
  trickling filters, 193
Records and reports
  see Chapter 19
Reducing agent, 332
Reliquefaction, 369
Retention time, 128
Reuse
  see Chapter 7, *ADVANCED WASTE TREATMENT*
Review of plans and specifications
  activated sludge, 265
  bar screens, 93
  chlorination, 371, 374
  chlorinators, 371, 374
  grit channels, 93
  oxidation ditch, 255, 265
  package aeration, 265
  ponds, 300
  primary treatment, 132
  racks, 93
  rotating biological contactors, 220
  screens, 93
  sedimentation, 132
  sulfonators, 371, 374
  trickling filters, 186
  wet wells, 93
Riprap, 290
Rotameter, 341
Rotating biological contactor
  abnormal operation, 216
  advantages, 208
  alkalinity, 212
  biomass, 211, 214
  bulkhead, 200, 212
  clarifiers, 200
  clearances, 211
  cold weather, 200
  contact time, 212
  covered, 200, 208, 220
  description, 200, 202, 203
  dissolved oxygen, 212
  drive units, 208, 218, 219
  efficiency of process, 208, 212
  effluent, 208, 212, 214
  energy use, 208
  equalization tanks, 208, 214
  flow diagram, 201
  flow equalization tanks, 208, 214
  growth, 200, 214
  holding tanks, 200
  housekeeping, 217
  hydraulic balance, 211
  hydraulic loading, 208, 212, 220, 221
  industrial waste treatment, 212
  influent, 212, 214
  inspecting new contactors, 211
  layout, 205
  limitations, 208
  loadings, 220
  lubrication, 211, 216, 217
  maintenance, 208, 211, 216, 217
  media, 200, 203, 204, 214, 217
  metric calculations, 221, 222
  nitrogen removal, 208, 212, 220, 221
  odors, 214, 215, 216
  operation, 211
  operational strategy, 211
  organic loading, 208, 212, 214, 220, 221
  parts, 206
  performance, 212
  pH, 212
  plans and specifications, 220
  power outage, 216
  pretreatment requirements, 208
  purpose, 206
  recirculation, 211, 212, 214
  recordkeeping, 211
  rotation of media, 211
  safety, 211, 216, 220
  sampling, 212
  shutdown, 216
  slime growth, 200, 211, 214
  sloughing, 200, 211, 214, 216
  sludge deposits, 214
  speed of rotation, 211
  stages, 200
  start up, 208
  sulfur compounds, 213
  supernatant treatment, 214
  temperature, 200, 211, 212, 220
  time of contact, 212
  toxic wastes, 214
  trend chart, 213
  troubleshooting, 211, 212, 215, 218
  underdrain, 206
  visual inspection, 211, 214, 215
Roughing filter, trickling filter, 167

S

SVI, 132
Safety hazards
  also see Chapter 14 and Chlorine safety
  activated sludge, 240, 250
  bar screens, 64, 67
  barminutors, 76
  causes, 60
  chlorination, 354
  chlorinators, 354
  chlorine, 354
  clarifiers, 122, 134
  comminutors, 74, 76
  cyclone grit separators, 89
  grit channels, 84
  grit washer, 90
  hypochlorinators, 333, 341
  National Safety Council, 60
  oxidation ditch, 255, 265
  package aeration, 250
  ponds, 297
  primary treatment, 122, 134
  racks, 64
  rotating biological contactors, 211, 216, 220

  sedimentation, 122, 134
  sulfur dioxide, 377, 378, 379
  trickling filters, 183, 187
Safety program
  see Chapter 14
Salmonellosis, 329
Sample size
  see Chapter 16
Sampling
  also see Chapter 16
  activated sludge, 250
  combined sedimentation-digestion unit, 139
  composite, 119, 212, 295
  grab, 212, 295
  oxidation ditch, 256, 257
  package aeration, 250
  ponds, 294
  primary treatment, 119
  rotating biological contactors, 212
  sedimentation, 119
  trickling filters, 171, 173
Sand drying beds, 45
Sanitary landfill, 51
Sanitary sewers, 29
Saprophytes, 329
Screening
  disposal, 37, 64, 69
  quantity, 69
  wastewater, 37
Screens
  see Bar screens
Screw lift pumps
  see Chapter 15
Scum
  pumping, 121
  receiving water, 17
  removal, 122
Scum and foam control, anaerobic digester
  see Chapter 12
Secondary clarifiers
  activated sludge, 128
  description, 43
  operation, 128
  oxidation ditches, 256, 257, 260, 266
  sludge collection, 128-131
  trickling filter, 128
Secondary treatment, 30, 42, 159, 200, 234
Sedimentation
  abnormal operation, 116
  description, 106
  detention time, 125
  drawing, 40, 41, 107, 108
  efficiency of process, 39, 110, 127
  effluent, 119
  flow diagram, 107, 108
  hydraulic load, 121
  influent, 119
  maintenance, 115, 122, 134
  operation, 115, 124, 232
  operational strategy, 115
  overflow rate, 126
  parts, 109, 110, 112
  performance, 127
  plans and specifications, 132
  primary clarifiers, 125
  pumping, 121
  purpose, 106, 112
  record keeping, 122, 151
  safety, 114, 122, 134
  sampling, 119
  scum removal, 39, 121
  secondary clarifiers, 30, 43, 128
  section, 109
  short-circuiting, 125
  shutdown, 115
  sludge and scum pumping, 39, 121
  solids loading, 127
  start up, 114
  surface loading, 126
  temperature, 125
  toxic wastes, 116, 118
  troubleshooting, 116, 117, 120
  types of units, 124
  weir overflow rate, 126
Sedimentation-digestion unit
  abnormal operation, 142
  description, 136
  digestion, 141
  efficiency of process, 136, 138
  flow diagram, 136
  maintenance, 142
  operation, 141
  operational strategy, 142
  parts, 138
  purpose, 138
  safety, 142
  sampling, 139
  section, 137
  sedimentation, 141
  shutdown, 142
  start up, 138
  troubleshooting, 142
Septic, 250
Septic tanks, 144
Septicity, 116, 375
Series operation
  ponds, 290
  trickling filters, 178
Settleable solids, 172
Settleability test, 239, 250
  also see Chapter 16
Settling
  see Sedimentation
Settling tanks
  activated sludge, 234, 239, 249, 250
  oxidation ditches, 256, 257, 260, 266
  oxygen activated sludge
    see Chapter 2, *ADVANCED WASTE TREATMENT*
  package aeration plants, 249, 251
  rotating biological contactors, 200
  trickling filter, 128
Settling velocity
  grit, 82
  particles, 124
Sewer systems, 29
Sewer-use ordinance, 179
  also see Chapter 5, *INDUSTRIAL WASTE TREATMENT*
Shigellosis, 329
Shock load, 173
Short-circuiting
  clarifiers, 125
  density, 125
  ponds, 300
  sedimentation, 125
  temperature, 125
Shredding, 37
Shutdown
  activated sludge, 249

  aerated grit chambers, 86
  bar screen, 68
  barminutors, 76
  chlorination, 349
  chlorinators, 349
  comminutors, 76
  cyclone grit separators, 89
  grit channels, 84
  grit washer, 90
  oxidation ditch, 260
  package aeration, 249
  ponds, 292
  primary treatment, 115
  rotating biological contactors, 216
  sedimentation, 115
  sulfonator, 387
  trickling filters, 170
SI system
  see Metric
Sixty-minute settling test, activated sludge, 239, 250
Slingers, 262
Sloughings, 128
Sludge
  definition, 39, 121
  dewatering, 45
  digestion, 45
  disposal, 45
  gravity dewatering, 45
  heat drying and incineration, 45
  incineration, 45
  lagoons, 45
  multiple hearth incinerators
    see Chapter 3, *ADVANCED WASTE TREATMENT*
  pumping, 121
  receiving waters, 17
  wet oxidation, 49
Sludge age, activated sludge, 241
Sludge blanket, 239
Sludge bulking
  activated sludge, 249
  toxic waste, 118
Sludge collection
  collector failure, 118, 121
  primary sedimentation, 121
  secondary sedimentation, 128-131
  start up, 114
Sludge density index
  activated sludge, 232
  test, 232
Sludge deposits, ponds, 284
Sludge dewatering, 45
  also see Chapter 12 and Chapter 3, *ADVANCED WASTE TREATMENT*
Sludge disposal, 45
Sludge handling
  also see Chapter 12 and Chapter 3, *ADVANCED WASTE TREATMENT*
  aerobic digester, 45, 241
  anaerobic digester, 45
  primary sedimentation, 121
Sludge pumping
  anaerobic digester
    see Chapter 12
  failure, 118
  operation problems, 118
  primary sedimentation, 121
Sludge thickening and conditioning
  see Chapter 3, *ADVANCED WASTE TREATMENT*
Sludge treatment
  see Chapter 12 and Chapter 3, *ADVANCED WASTE TREATMENT*
Sludge volume index
  activated sludge, 132
  test, 132
Snails, trickling filter problems, 174
Sodium chlorite, 371
Sodium hypochlorite disinfection, maintenance, 371
Soil conditioner, 51
Solar heat, 212
Solids
  also see Chapter 3, *ADVANCED WASTE TREATMENT*
  dewatering, 45
  digestion, 45
  disposal, 30, 45, 50
  dissolved, 19
  filterable residue, 19
  floatable, 20
  handling, 45, 46, 47
  inorganic, 20
  land application
    see Chapter 3, *ADVANCED WASTE TREATMENT*
  loading on clarifiers, 127
  nonfilterable residue, 19
  nonsettleable, 19
  organic, 20
  settleable, 19
  suspended solids, 19
  test in wastewater, 19
  total, 19
  wastewater characteristics, 19
Solids accumulation, rotating biological contactor, 214
Solids loading
  activated sludge clarifiers, 128
  dissolved-air flotation, 127
  secondary clarifiers, 127
  sludge thickening, 127
Soluble BOD, 208
Specific gravity, 124
Stabilization ponds, 49, 282
Stabilized waste, 234, 279
Standard rate
  anaerobic digester
    see Chapter 12
  trickling filter, 167, 184
Start up
  activated sludge, 245, 248
  aerated grit chambers, 84
  bar screens, 68
  barminutors, 76
  chlorination, 342, 344
  chlorinators, 342, 344
  comminutors, 76
  cyclone grit separators, 89
  grit channels, 84
  oxidation ditch, 255, 256
  package aeration, 245, 248
  ponds, 287
  primary treatment, 114
  rotating biological contactors, 208
  sedimentation, 114
  sulfonator, 381, 382, 384
  trickling filters, 169
Sterilization, 50, 329
Storm sewers, 29
Storm water, 177
Sulfonator
  abnormal operation, 386
  controls, 380

  - dechlorination, 376
  - diaphragm, 377
  - differences, 386
  - emergency safety equipment, 379
  - evaporator, 380, 387
  - feed-rate control, 380
  - leaks, 382
  - maintenance, 387
  - operation, 381, 386
  - operational strategy, 386
  - pipeline cleaning, 381
  - recordkeeping, 387
  - shutdown, 387
  - start up, 381, 382, 384
  - troubleshooting, 383, 385, 386
  - water supply, 382
- Sulfur dioxide
  - application point, 377
  - chemical reactions, 377
  - containers, 379
  - controls, 380
  - dechlorination, 37, 50, 376
  - detection of leaks, 378
  - emergency safety equipment, 379
  - evaporator, 380, 387
  - feed rate, 380
  - first aid, 378
  - flow measurement, 377
  - hazards, 377
  - injector, 380
  - leaks, 378
  - maintenance, 387
  - odor, 376, 377
  - physiological response, 378
  - piping, 379
  - properties, 376, 377
  - purpose, 376
  - reactions, 377
  - repair kit, 378, 379
  - residual, 381
  - safety, 377, 378, 379
  - shutdown, 387
  - start up, 381, 384
  - sulfonator, 380
  - supply system, 379
  - troubleshooting, 383, 385, 386
  - use, 37, 50
  - valves, 379
- Supernatant, 45
- Surface aerators, ponds
  - applications, 291
  - description, 292, 294
  - maintenance, 294
  - operating time, 294
  - parts, 294
  - purpose, 294
- Surface loading
  - activated sludge clarifiers, 128
  - clarifiers, 126
  - trickling filter clarifiers, 128
- Suspended solids, 171

T

- Temperature effect
  - activated sludge, 249
  - anaerobic digester
    - see Chapter 12
  - chlorination, 333
  - clarifiers, 125
  - oxidation ditches, 260
  - ponds, 284, 287, 290
  - rotating biological contactor, 211, 212, 252
  - sedimentation, 125
  - short-circuiting, 125
  - trickling filter, 165, 174, 177
- Terminology, wastewater treatment, 405
- Tertiary treatment, 37, 282
- Tests
  - activated sludge, 250
  - combined sedimentation-digestion unit, 139
  - effluent disposal
    - see Chapter 13
  - oxidation ditches, 256, 257
  - package aeration, 250
  - ponds, 294
  - primary sedimentation, 119
  - rotating biological contactors, 212
  - trickling filters, 171, 173
- Thermal wastes, 17
- Thermophilic process, anaerobic digester
  - see Chapter 12
- Titrate, 336
- Total coliform, test
  - see Chapter 16
- Toxic wastes
  - activated sludge, 240, 249
  - combined sedimentation-digestion unit, 142
  - general, 17
  - oxidation ditch, 252, 257
  - package aeration, 240, 249
  - ponds, 286, 291, 299
  - primary treatment, 116, 118
  - rotating biological contactors, 214
  - sedimentation, 116, 118
  - trickling filters, 165, 178
- Training opportunities, 7
- Treatment plant operator
  - duties, 1, 5, 6
  - employers, 1
  - pay, 1
- Treatment plants, 30
- Treatment processes, 30
- Trend chart
  - activated sludge, 250
  - oxidation ditches, 259
  - ponds, 296
  - rotating biological contactors, 213
  - trickling filters, 174, 175
- Trickling filter/solids contact process, 186
- Trickling filters
  - abnormal operation, 174, 177
  - chlorination, 169, 176, 178, 179
  - clarifiers, 128
  - classification of filters, 167
  - cold weather, 177
  - covered, 177, 187
  - distribution system, 159, 181, 187
  - dosing tanks, 165, 166
  - downstream process problems, 179
  - efficiency of process, 171
  - effluent, 169, 171
  - energy use, 165, 170, 173
  - filter flies, 176
  - flow diagram, 160
  - growth removal, 171
  - high-rate filters, 167, 184
  - hydraulic loading, 173, 184, 185
  - industrial waste treatment, 165, 178

  influent, 171, 177
  inspecting new filters, 169
  layout, 161
  loadings, 184
  maintenance, 181
  media, 159, 184
  odors, 176, 187
  operation, 165, 170, 173
  operational strategy, 173
  organic loading, 173, 185, 186
  parallel operation, 178
  parts, 163
  performance, 171
  plans and specifications, 186
  ponding, 174, 179
  recirculation, 165, 170, 172, 174, 183
  recordkeeping, 193
  roughing filters, 167
  safety, 183, 187
  sampling, 171, 173
  section, 162
  series operation, 178
  shutdown, 170
  site, 186
  sloughing, 165, 171
  snails, 174
  solids contact, 186
  stages, 167, 168
  standard-rate filters, 167, 184
  start up, 169
  temperature, 165, 174, 177
  toxic wastes, 165, 178
  trend chart, 174, 175
  troubleshooting, 171, 174, 177, 179
  underdrains, 159, 183
  upstream process problems, 179
  ventilation, 165, 176
  visual inspection, 173
  zoogleal film 159
Troubleshooting
  activated sludge, 249
  bar screens, 68
  barminutors, 76, 92
  chlorination, 350, 351, 352
  chlorinators, 346, 350, 351, 352
  chlorine, 350
  combined sedimentation-digestion unit, 142
  comminutors, 76, 92
  grit channels, 76, 92
  oxidation ditch, 258, 260
  package aeration, 249
  ponds, 288, 291, 298
  primary treatment, 116, 117, 120
  rotating biological contactors, 211, 212, 215, 218
  sedimentation, 116, 117, 120
  sludge collector, 118
  sludge pump, 118
  sulfonator, 383, 385, 386
  sulfur dioxide, 383, 385, 386
  trickling filters, 171, 174, 177, 179

Turbidity test
  see Chapter 16
Typhoid fever, 18, 329

U

Untrafiltration, 308

V

Vacuum filtration, operation
  see Chapter 12 and Chapter 3, *ADVANCED WASTE TREATMENT*
Valves, maintenance
  see Chapter 15 and Chapter 7, *INDUSTRIAL WASTE TREATMENT*
Velocity of settling,
  grit, 82
  particles, 124
Ventilation, safety, 93
Venturi meters, 39
Viruses in wastewater, 329
Visual inspection
  activated sludge, 248, 250
  oxidation ditch, 256-258
  package aeration, 248, 250
  ponds, 289, 290, 293, 296
  rotating biological contactors, 211, 214, 215
  trickling filters, 173
Volatile acids, test
  see Chapter 16

W

Washing, grit, 90
Waste discharges, 16
Waste treatment ponds, 30, 32, 49
Wastewater characteristics, 18
Wastewater treatment objectives, 16, 23
Wastewater treatment processes, introduction, 25
Wasting activated sludge, 248
Water, 16
Water Pollution Control Federation, safety surveys, 61
Water quality protector, 4
Weed control, ponds, 289
Weirs
  diameter, 126
  flow measuring, 39
Weir overflow rates
  activated sludge clarifiers, 128
  primary clarifiers, 126
  trickling filter clarifiers, 128
Wet oxidation, 49
Wet wells
  review of plans and specs, 93
White biomass, rotating biological reactors, 214
White foam, activated sludge, 248

Z

Zoogleal film, 159